
WORLD RADIOGRAPHY DAY
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Elevating Patient Care with ARTIFICIAL INTELLIGENCE
Radiographers are essential in elevating patient care with artificial Intelligence.

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In this Special Edition, articles and reports by authors/societies do not necessarily reflect or represent the opinion and thesis of the ISRRT.

Message from the ISRRT President

By Donna Newman

Dear ISRRT Members and Radiography Professional Stakeholders,

WORLD Radiography Day will be celebrated on November 8,2020 around the world by our profession.

As we celebrate it is good to know that we all have played a vital role in the delivery of medical imaging and radiation therapy for patients all over the world. I'm thrilled to share this second special addition of World Radiography Day "Elevating Patient Care with Artificial Intelligence: Radiographers are essential in elevating patient care with artificial Intelligence". The theme which was chosen to raise awareness, help educate and shape the perception of the vital role radiographers/ radiologic technologists play as part of the health care team in elevating patient care while using artificial Intelligence during our work day.

Today, we see Artificial Intelligence (AI) providing useful tools for the radiographer's daily practice to enhance workflow, including worklist designations, workflow distributions and scheduling assistance relating to reducing no shows, appointments and repeat examination.

Also available today is AI software that can help to automate Quality control, lower radiation dose, improve positioning and improve sequencing in imaging.

AI is being used in specialties such as MRI, CT, Nuclear Medicine, Hybrid Imaging and Molecular Imaging such as PET CT and PET MRI to improve image acquisition and sequencing as well as enabling radiation dose reduction, reduction in imaging time and enhancing postprocessing.

Machine learning software has been developed to help position patients in the iso center when performing scanning which help ensure faster speed and precision while ensuring use of optimal exposure control. These tools can help lower dose and improve image quality contributing to the efficiency and increase in patient safety.

AI technology is also allowing for dual energy detectors to image both soft tissue and bone density in one imaging procedure which also allows improvement in image quality while reducing patient dose.

AI tools in sonography and echocardiography are aiding in mapping patient anatomy, improving reproducibility which will improve image quality. AI systems have helped achieve accurate measurement of Left Ventricular Ejection Fraction (LVEF), which has contributed to consistent and accurate results.

AI tools in radiation therapy have brought about improved access to the patient's diagnostic imaging, creation of AI contours, dose calculation for the scheduled plan as well as AI driven adapted treatment plan, evaluate, check plan and deliver.
ISRRT has collaborated with ISRRT member experts, ISRRT member societies and regional stakeholders to highlight some of these AI technological advancements used when performing medical imaging and Radiation Therapy procedures.

ISRRT hopes that this educational material will demonstrate and highlight how radiographers, as experts, use their critical thinking and judgement when evaluating positioning and determining if adjustments are needed for software settings when incorporating these AI tools.

Additionally, ISRRT hopes this addition captures the essential aspects that radiographers play in patient communication, patient assessment, patient monitoring and most importantly the human touch during patient care during a procedure.

We hope you enjoy this publication and that you will find relevant resources, educational tips and ideas that will help radiographers / radiological technologist elevating patient care with Artificial Intelligence.

Additional with our members and health professionals around the world we hope that by reading this edition and incorporating what you learn from our authors you will help drive the ISRRT key messages of creating, influencing and impacting change within your country and daily practice. As AI technology advances radiographers will focus on what they do best, to act as an interface between the patient and imaging and radiation therapy procedures and use their compassionate human touch to care for the patient during those difficult times for patients which is essential for the delivery of an efficient, effective and caring health care system.

An insight into Danish radiography and the work with Artificial Intelligence (AI)

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THE Danish Healthcare System is one of the most developed in the world and with free hospital service to all citizens, we welcome AI as the technology which can make the best use of resources for the benefit of the patient, the diagnostics and treatment. Danish Council of Radiographers has asked two radiology departments in different part of Denmark to give their vision about AI in the future of radiology with focus on challenges and benefits.

Aspects of Artificial Intelligence (AI) in radiography

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New technologies are moving forward and we, Radiographers need to keep our focus on how these inventions can increase patient care or help us increase patient care.

As we speak, the population of citizens above the age of 80 is growing and by 2057, estimated one in ten citizens in Denmark will be 80 years + compared to today where 4.4 % of the population are above 80 years old. Currently the 4.4 % of 80 + years old's use 10 % of the local GP's capacity so this means we need to prepare our healthcare system to embrace the increased demands the future holds. In radiology, this will result in more scans and increased demand for interventional radiology, more requests for mobile radiology such as bedside ultrasound, X-rays performed in nursing homes and other time-consuming patient related tasks. With no increase in government funding, we must find ways to improve our organizations and start working towards identifying areas where AI can help us create the necessary time and prevent radiographers and other professionals in radiology departments get ill from stress related symptoms.

So where and how can we start? We can for instance start by identifying which time-consuming tasks we perform today and continue by identifying which of these tasks new technologies/AI can manage.
Here are a few examples of tasks we spend time doing and instead we can use this time to create excellent patient care:

- We spend time positioning the patients correctly in CT scanners. If the scanners can be built to identify the correct iso-center for the patient, the correct start and finish for the scout image and corrections for any abnormalities, the radiographers can concentrate on the patient.
- We spend time finding blood test results prior to patient examinations. If an AI system can identify which blood tests we need for a given examination, send a notification to the patient and the laboratory and place the results in the RIS system, the radiographer and the booking personal can save time.
- We spend time creating reconstructions of CT scans. This should be an easy task for AI.

The radiologists and radiographers spend time measuring vessels prior to interventional radiology. If AI can measure vessels from the CT/MRI scans and identify the equipment we need for the operation, this can free a lot of time.

Quality assurance is another area where AI can help us create a safer environment for our profession and our patients:

- Help guide to correct positioning when taking X-ray images.
- Help guide for the exact correct amount

of mA, time and kV for each patient examination according to the potential diagnosis asked for in the referral, meaning another image quality is required for scoliosis than for chest examination or between a first time image and a control image of a fracture.
- Automatic identification of right and left according to the patients anatomy, and prevent wrong side markers.
- Let the system report if the dose product for an examination changes according to the normal used protocols.

Also, in the booking process, AI can contribute:
- Ensure that patients needing reoccurring control scans get booked in the same scanner or x-ray room.
- Book certain patient studies such as children, dementia patients or other specialized patient categories on days where specially trained radiographers are at work.
- Ensure that patients needing reoccurring imaging are booked to meet the same radiographer each time they come.
- Overview and note on the screen for the radiographer if the patient has experience with the specific examination referred to, to optimize the radiographers communication and possibilities to help the patient thought he examination.

We also need to think ethics into areas where AI can contribute and remember to think the patient experience into the equation. An example can be software in MRI that helps decide the amount of frequencies required for correct diagnosis. If the software detects any pathology in the first frequency it will decide for more frequencies, but if it finds no pathology the scan will end. This software will save time but can potentially give the patient an idea of the result according to the length of time spent in the scanner and cause the patient anxiety.

Elevating patient care with Artificial Intelligence

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Radiography is changing and it is changing very fast!

The development and use of Artificial Intelligence (AI) is growing rapidly these years and it is, without any doubt, here to stay. In the following, I will try to describe, how we work with AI at my department, and how we think it will elevate the Patient Care in the years to come. By Patient care I mean the quality of examinations, images and reports but also the possibilities that the technology gives radiographers to increase the quality of the specific way we treat and take care of patients.

As we all know, the imaging options are increasing, and to help us all manage the increasing numbers of examinations and images, not to mention the lack of radiologists, we need to find areas, where AI can help us save more time and, at the same time, increase quality of all we do.
In the Capital Region of Denmark, where I work, there are a lot of initiatives to develop and implement AI directly into clinical practice. Many of these initiatives are performed as private and public cooperation and many of the hospitals and radiology departments in the region is involved in the process. These initiatives are performed in the areas of neuro-, abdominal-, thoracic- and musculoskeletal radiology.

At my department, almost all of the work related to AI is handled by our Professor and his staff. He is a very broadly embracing and innovative radiologist, and therefore a lot of the work is handled as a fusion of the classic way of research and modern innovation. The benefit for our patients is obvious. We seek to implement AI on the fly and as soon as we trust the results. At the moment, most of our projects is performed in the area of musculoskeletal radiology and we work closely with private partners and developers.
The professionalism of radiography is changing rapidly and the transition from 2D to 3D is going to change our profession even more, I think. We will still perform a certain amount of conventional images, but I think we will see a huge increase in 3D-images in both the musculoskeletal area as well as in the thoracic area. In this transition, AI will have a big impact. And we must not fear this transition – we need to embrace it!

AI will help us all optimize workflows and precision in the outcome. It will help radiologists so they can spend their time more wisely and put their efforts where it is needed. But it will also help radiographers to be able to concentrate more efficient on the patient care itself, and thereby to focus even more on the humanity part of our job. In my point of view, AI will have the following value and effect:

It will promote the – quality, efficiency, patient safety, speed and precision.

It will reduce the – lack of radiologists, radiation doses, use of contrast agents, image noise, number of retakes and errors, costs and moral injury (burnout) of staff.

As radiographers in the ongoing transition, we must not forget the humanity part of our job and we need to secure, that we are up to speed with the upcoming technologies. Let us embrace AI.

And on top of the comments above, I have not even mentioned the arrival of robots in radiography/radiology. Who knows – we might even end up with a self-service CT-scanner?

Does the future of AI in medical imaging have a home in the developing world?

By Ramona Chanderballi, Guyana

Ramona Chanderballi

Ramona entered the medical imaging field with her Certificate in Radiography in 2010 from the Ministry of Health, Guyana.

She was employed as an X-Ray Technician at the Georgetown Public Hospital Corporation, Guyana from 2010 to 2014 when she left to complete her BSc in Medical Imaging at the University of Guyana where she graduated in April 2018.

She is the owner and blogger of RadToTheBone592, the first medical imaging blog in Guyana. Ms Chanderballi is currently a cardiac sonographer at the Georgetown Public Hospital Corporation and is the first female cardiac sonographer. She served as the WRETF Ambassador for Guyana July 2018 to July 2019, and currently sits as the youngest Trustee on the WRETF Board where she functions as the Ambassador Program Director.

Ramona is currently in training for pediatric echocardiography.

Introduction

WORLD Radiography Day 2020 is themed "Elevating patient care with AI; Radiographers are essential in evaluating patient care with AI". Artificial intelligence, simply put, is computer programming learning to think like humans. While this may be the new cutting-edge technology in the radiology world, does AI in medical imaging have a home in the developing world?

The earliest known publication of an AI article was in the 1950s, about 60 years since the discovery of x-rays by Wilhelm Roentgen. And with the massive, rapid advancements the medical imaging field has seen in the last few decades, it was only a matter of time before AI became a major player in the technology used in the radiology. MRI, CT, plain film radiography, hybrid and molecular imaging have all successfully employed AI in image interpretation,echocardiography has been catching up in the last few years.

Echocardiography in the developing world

Guyana is a country with a population of about 800,000 and is classified as a low to middle income developing country. There are currently only five American Society of Echocardiography (ASE) level trained cardiac sonographers performing echocardiograms in Guyana. This translates to one cardiac sonographer for every 160,000 persons. Of the five full time cardiac sonographers, only one is trained in the performance of pediatric echocardiography with a second cardiac sonographer currently in pediatric training.

This small number of qualified cardiac sonographers is inadequate to meet the demands for echocardiography in Guyana, and a similar lack of appropriately qualified and experienced sonographers exists in many, if not most, developing countries. Given the important role of echocardiography in the identification and management of heart disease, the leading cause of death in most developing nations, mechanisms to improve access to cardiac diagnostics must be sought in order to improve patient care and outcomes.

How can AI help?

In 2019, FDA gave clearance for the echocardiography image analysis system "EchoGo Core" for commercial use by clinicians. Some of EchoGo capabilities are for automated performance of parameters such as Left Ventricular Ejection Fraction (LVEF) and global longitudinal cardiac strain, among others. At this point, cardiac strain analysis is not routinely utilized in many centres and is not available in Guyana. However, LVEF is routinely evaluated, and is an essential component of each echocardiographic study. Accurate measurement of LVEF, like many other aspects of echocardiographic study is subject to operator experience and diagnostically accurate image quality. The use of AI systems can reduce user variability in both calculation and interpretation, leading to more consistent and accurate results.

According to a study published in 2018 by Alsharqi et al, from 2007 to 2018 AI was able to learn calculation of EF and longitudinal strain, quantification of wall motion abnormalities, quantification of mitral regurgitation, classification/discrimination of pathological patterns (Restrictive cardiomyopathy vs cheat pain, and Hypertrophic cardiomyopathy vs Athlete's heart in 2016), assessment of myocardial velocity, and recognition of 15 echocardiography views.

Role of AI in enhancing accuracy of echocardiography in a limited resource setting

It takes on average of 10 years for a physician to complete medical school and specialty training to attain proficiency in echocardiography. For cardiac sonographers, it can take anywhere from 2 to 4 years of university education, then at least 5 more years to become adequately proficient. In resource limited countries, patients cannot wait years for services the need now.

The use of machine assisted learning in echocardiography was highlighted in a paper published by the American Society of Echocardiography titled "Artificial Intelligence and Echocardiography: A Primer for Cardiac Sonographer". Algorithms were developed to give guidance to new sonographers on technically correct image acquisition by the software recognizing incorrect or off axis views and providing real time guidance on how to move the probe to acquire the correct image.

The paper also highlighted advantages of AI assistance in a high patient volume echocardiography lab. With the increased need for echocardiographic studies in a population with longer life spans and body mass indices, sonographers are at a higher risk of musculoskeletal injuries. Automated acquisition could possibly serve as a solution to improve the ergonomic burden sonographers face with increased patient volumes.

AI implementation in the developing world

Despite the significant costs of AI implementation, there are several AI programmes being tested in various parts of Africa and India in the health industry with the potential for reproducibility in other resource limited communities.

In an interview with SciDev.Net, Wadhwani Institute for Artificial Intelligence senior programme director- Mr Neeraj Agrawal outlined 7 questions Wadhwani AI uses to decide whether or not an AI project will benefit a community. The questions he outlined are: Is this a big problem? Does it have an AI solution? Will solving the AI part make enough of a difference? Will the solution be accepted by stakeholders? Does the data exist, or can it be created easily enough? Are there partner organizations that can co-create and pilot the solution? Are there existing programmes and pathways to scale?

Although AI is costly and is currently exploring its uses in the developed world, partnerships between low- and middle-income countries and high-income countries are being studied with the hopes of broader reproducibility. But limitations exist in technological infrastructure, human expertise, and legislature.

According to the International Development Innovation Alliance (IDIA), there are currently 4 billion people without internet services. Until plans can be put in place to ethically integrate AI in finding solutions in a limited resource setting, AI will widen the gap between the services is has available and who can afford to access them.

AI, Echocardiography and the future

AI, while of significant potential benefit in the provision of cardiac diagnostics, can never replace the importance of the one-to-one interaction between the cardiac sonographer and the patient. Echocardiography will always remain both an art and a science. Utilizing the best available technology is critical to optimizing the performance and interpretation of echocardiographic studies by the cardiac sonographer and the interpreting physician, but will not negate the role of the human art of medicine.

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Radiographers are essential in elevating patient care with Artificial Intelligence

By Edward Chen, Hong Kong

Edward Chan

Edward achieved his basic radiography training in Hong Kong and Australia and has two Master Degrees in Psychology and Health Care. He is the Vice-President of Hong Kong College of Radiographers and Radiation Therapists. From 1998 to 2012, he was the Chairman of the Hong Kong Radiographers' Association. He organised various functions throughout the years, such as continuing education programs & assessments, newsletters, seminars & conferences. Promoting professional development, liaising with local and overseas relevant organisations are his missions throughout these two decades. Providing expert recommendations to Government and related institutes about medical imaging services are his duties of the professional bodies. Standard of Practice and Radiation Protection is the focus of his career. Besides that, Edward has been the Certified Professional Healthcare Information and Management System (CPHIMS) since 2008. He is one of the founders of medical imaging informatics profession in Hong Kong. Recently, AI development of radiography becomes his new studying topic.

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Introduction

AI in Healthcare service is springing up like mushrooms in the last decade, especially in radiology services. An AI article in the recent Healthcare Weekly has tried to illustrate the renouncing AI products. There are nine out of twelve products[1] related to radiology or medical imaging. However, all of the radiological AI products are supporting the diagnosis, serving the radiologists. Does AI help the radiographers or radiological technologists? And does it elevate the patient care? This article is trying to organize the information of healthcare AI to see whether radiographer can apply the AI and our role of its development. I hope this article can inspire you to have more new idea of AI development in radiography.

Clinical application of AI

The term AI was first used in 1956 by a group of scholars and computer scientists of Dartmouth College. They made it to describe the machine which could solve problems as the human using natural intelligence.[2] After over 60 years of development, AI is affecting our daily life even though you may not notice. It has been used in areas such as the auto-braking system of your car and the auto customer relationship system either online or on the phone.

In the healthcare field, the author of Healthcare Weekly, Cordrin Arsene, gave a summary of the AI applications[1] which consist of two dimensions, Decision Support and Information Management.

– Decision Support

It is like most of the AI tools in the radiology department. They are helping the radiologist to find out the lesion from the images by faster and more accurate pattern recognition and providing the clinical suggestion, such as the most common lung nodules or lesion recognition of virtual colonoscopy of CT. Those tools are trying to do early detection and improve efficiency.

– Information Management

It is like the communication system of the patient and healthcare professionals, such as the mentioned auto customer relationship system. Some RIS vendors can provide the AI self-booking system for the patients. Nowadays, many HIS can provide allergy or contra-indication alert to the radiographer or nurse before the examination. Those tools can minimize human error. Some radiography school has installed the VR teaching system, which is another format of AI tools of information management.

Roles of Radiographer in AI application

As I mentioned, we have applied AI in medical imaging for some time. Many healthcare professionals have joined the development and research of AI business. Directly speaking, there are two groups of people in AI application, User and Developer.

– User

Radiographers, as a user, provide efficient and accurate services by AI assistance, such as automatic 3D processing, lung nodule detection and fracture detection.[1] They understand the operation of the AI system and know how to interpret the results of AI. The interpretation is the most important of AI application to deliver clinical service. Black box difficulty is a jargon of AI. That means AI cannot ask "why" during their learning process. AI, either deep learning or machine learning, is trying to find the pattern of the datasets. The logic behind the result is not well defined. Users' expertise becomes essential for interpreting the decision and limiting the negative implication.

– Developer

Radiographers can be an AI developer by joining AI researches and providing professional opinions to develop AI algorithms. Helping to collect meaningful data for AI learning is essential to build up the AI system. Radiographers can take this role well too.

generated various protocols. Bodyweight, age, heart rate and BP can affect the contrast bolus flow and enhancement of the organs. With AI support, radiographer could have a personalized injection protocol to achieve the best enhancement. So, we need datasets of different patient types for

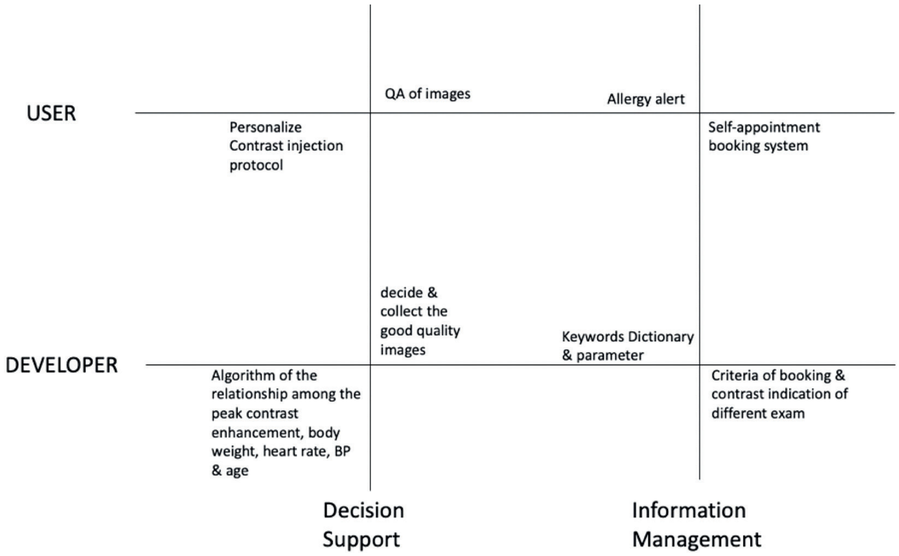

Diagram 1: Roles and Applications of AI in radiography.

Examples of elevating patient care

With the applications and roles, I made a diagram to illustrate the examples of usage and position of radiographers that they can take part in AI. The information on it is inexhaustive. You are welcome to add more in the future.

– QA of images

Some research groups have developed their AI systems to check the quality of the radiographs. They can maintain the quality of images for the radiologist to report. Radiographers have to select a lot of standard radiographs for the system to learn. The AI system can give a rating and the false of the quality. In reality, the operating radiographer has to decide whether to accept its comment or not.

– Personalize CT contrast injection protocol

Some researchers have developed the AI systems to learn the difference of full dose contrast MRI images and low dose contrast images[3]. Then the system can reconstruct the low dose images as the full dose quality. My example is a hypothetical system. As we all know, it is a challenge to achieve the best contrast enhance result during the CT contrast exam even though we have tons of researches studying about it and the AI to learn the contrast enhancement pattern. Indeed, the professional who gives the injection has to decide trust or modify the protocol in practice.

– Allergy and contrast-indication Alert

Straightly speaking, it is not an AI system. It is a keyword searching system within the patient information. Many HIS systems have this build-in. However, the continuous input of radiographers is necessary because the standards and requirements may change from time to time. The development of keywords dictionary must be a collaboration work among all healthcare professionals. I did that for my hospital's HIS. It was tedious, but the functions are useful for patient care.

– Self-appointment booking system

Some HIS and RIS services providers have introduced this function in their systems. For RIS, examination booking is complicated because the system has to consider the contrast indication, preparation, availability, etc. AI should gather all the information to provide a recommend time slot for the patient to accept or allow the patient to choose a possible one. On the other hand, the system should provide all the necessary information for them to know and follow.

Summary

AI is a concept for a long time. With the advancement of computing technology, it is becoming part of our daily life. The motivation for developing AI is similar to create tools, such as CAD (Computer Aided Diagnosis) tools and AEC (Automatic Exposure Control). Those are helping us to speed up the process and reduce the error. AI is serving the same. I want to quote a statement of Dr Nick Woznitza, co-chair of EFRS-ISRRT working group on AI. "Radiographers may act as the gatekeepers to medical imaging, using AI as a decision support tool to ensure the examination performed is correct." he made it in an interview by ESR[4]. To embrace AI in radiography, we need a good foundation in our basic professional knowledge and the theory of AI development. Those are the elements to be a gatekeeper either in the application or development. The radiographers can refer "A Joint Statement of the International Society of Radiographers and Radiological Technologists and the European Federation of Radiographer Societies.[5]" It gave some cardinal directions about applying AI in our profession.

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Håkon Hjemly

Håkon Hjemly has been the ISRRT Vice President Europe Africa since 2018. He is Manager of Policy at the Norwegian Society of Radiographers. His main responsibilities for the society are related to professional role development of radiographers and to health political issues.

He has a Masters Degree in clinical health, focusing on role development for radiographers, and post graduate education in both digital imaging processing and in x-ray protection. Prior to the work for his Society, he had variety of roles in both the private and public sector in Norway; Clinical Radiographer, QA-administrator, Manager, Radiation Protection Officer, Product Specialist and Sales Representative (CT, Mammography and C-arm).

Håkon is also past president of the EFRS and served on the board for two terms. He is chairing on behalf of the ISRRT a joint project with the EFRS focusing on radiographers role with artificial intelligence.

Radiographers and AI, do we have to change our ethics?

By Håkon Hjemly, Norway

Introduction

A PROFESSION is often recognised by its own set of ethical guidelines. These ethical guidelines may be at both national and international level. This is also the case for radiographers/radiological technologists (radiographers), as many national societies have developed their own in addition to the international guidance by the ISRRT[1] or other regional recommendations.

Professional ethics delineates how broader ethical standards, such as responsibility, integrity, fairness, transparency and avoidance of harm apply to the basis of the profession. This includes such elements as safe, caring and a knowledge-based application of advanced technological equipment in the best interests of the patient, and that the radiographer`s interaction with the patient shall be based on respect for human rights, equality and justice.

Radiographers are the interface between medical imaging- and radiotherapy technology and patients. Patients rely on and trust the radiographer to make correct decisions. Radiographers often need to explain to their patients what is planned, why and what will be the next step in their diagnostic or therapeutic pathway. The rapid development of software tools, with so called artificial intelligence (AI) and machine learning (ML) features, challenges these ethical principles in different ways. Medical imaging exams and radiation therapy procedures will most likely be done at higher efficacy and speed, involving fewer professionals and include increased throughput of patients. Ethics depends on cultural values and changes over time and my question is whether current professional ethics needs to change or be looked at differently because of concerns with the accountability and trust in autonomous systems with respect to AI?

Matter of trust and the principle of informed consent

Because many choices made in radiology service are critical, it is necessary that they are rely on the trust between the players. Patients have the right to co-determination regarding decisions about themselves with the principle of informed consent important in most ethical guidelines for radiographers. This means in practise that radiographers should be able to educate and provide appropriate information to patients and/or family, so that they can understand and make informed decisions about their care. Also, if an AI system acts in a way that we do not anticipate or understand, claiming ignorance cannot absolve professional's ethical responsibility for the outcome.

I strongly believe that this ethical principle is important to have in mind when new systems based on AI are introduced. It is essential therefore that the patients have full confidence in the radiographers and the tools they use, no matter how advanced they are.

What do radiographers need to know?

Accountability for personal actions and for maintaining professional conduct is always relevant, but how far can accountability for the actions of an AI system be taken? AI technologies are not easy to understand for those not involved in their design and development, and even those with considerable knowledge on the subject often find it difficult to understand how software and devices with AI-content produce their output as their algorithms remain opaque. They rarely provide any human understandable explanation or justification for their predictions. This makes explaining the underlying logic of a particular system very difficult, as to how decisions were made, whether there are errors and how these might have occurred. One of the ways many have proposed to address this issue is through ensuring that how autonomous systems operate must be transparent to all the relevant stakeholders.

The term transparency also addresses

the concepts of traceability, explicability, and interpretability. Transparency is also essential for consent; no one can consent meaningfully when they do not understand the implications of consenting.

The important point here is that responsibility cannot only be in the hands of the designer or vendor, but it must be distributed across the process and its stakeholders. This requires that all stakeholders build awareness of possible issues, potentially including the use of risk assessment and verification tools.

The ISRRT and the EFRS jointly states[2] that it is essential that radiographers and radiological technologists:

- Ensure that all research involving AI systems is conducted in an ethical way, communicating with patients on how their data may be used to develop and test AI.
- Are involved in the piloting and research of algorithms prior to clinical implementation.
- Understand how algorithms arrive at decisions and probability errors within these decisions to enable effective communication of findings to patients.
- Maintain and develop core skills and competencies to act as a sense check to AI-supported clinical decisions (for example scan planning in CT, image interpretation triage).

This requires that radiographers need to know and be able to explain, at least in principle how AI based solutions delivers results with a high degree of accuracy and precision. It also requires confidence that there is control over the quality of the data which AI methods and models are based on, and not least which tests and measurements the programme is subject to in the validation process. Radiographers must be able to supervise and evaluate decisions and results that AI-tools produces and to override these if required

Need for lowering our ethical standards?

Radiographers are professionals; being part of a moral community of others who share the same responsibilities and being able to draw on the experience of others to navigate similar moral dilemmas, tough decisions or adverse consequences. Although professional guides and codes of conduct are not meant to be exhaustive checklists of how to be ethical in any given situation a radiographer might encounter, they are tools intended to help radiographers learn to judge what is 'appropriate'. But what if we experience that living up to our recommended ethical standards is becoming more and more challenging? For example, if we often find ourselves not able to understand or explain why our AI-powered systems act as they do? Would it not be better to just accept this and to adjust our ethical standards accordingly?

This is also what I questioned in the headline and in the beginning of this article; Do we need to change our ethical standards or look differently at them with respect to AI?

I think we don't.

I don't recommend our ethical standards to be lowered because AI is difficult to understand and explain. Lowering our standards when facing challenges is a dangerous pathway to choose and could lead to the profession being more and more obsolete. I think how we adapt to this game changing technology very much decides the future for the profession. Our patients and ourselves may trust such technology close to 100% in 10 years from now, but it is critical that we continue keep our professional standards high if we want to be in control of it. I believe we will see radiographers working with more responsibility and more independent from other professions with support of AI if we follow the recommendations in the joint ISRRT-EFRS Position Statement(2), that radiographers should adapt to this new technology with our professional standards in mind and make sure we together elevate patient care.

"It is of critical importance that radiographers and radiological technologists, as medical imaging and radiotherapy experts, must play an active role in the planning, development, implementation, use and validation of AI applications in medical imaging and radiation therapy, reinforcing the need for the technology to be targeted to the most pressing clinical problems. The optimal integration of AI into medical safety, clinical imaging and radiation therapy can only be achieved through appropriate education of the current and future workforce and the active engagement of radiographers and radiologic technologists in AI advancements going forwards."

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ISRRT INTERNATIONAL SOCIETY OF RADIOGRAPHERS & RADIOLOGICAL TECHNOLOGISTS

Naoki Kodama

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Future roles of radiological and technologists and medical Artificial Intelligence

By Naoki Kodama, Japan

IN recent years, owing to the remarkable development of information processing and communication technologies, the spread of electronic medical charts and the digitization of medical-related information are rapidly progressing in the medical field. Medical device manufacturers are developing artificial intelligence (AI)-based systems to effectively use these collected medical data to provide higher-quality medical care. In addition, as the early detection of diseases is expected to reduce medical costs, the Japanese government is supporting the introduction of AI technology in the medical field (medical AI).

While AI means "artificial intelligence", it is a program that reproduces the logical thinking performed by humans. Until now, it was a very limited intelligence that could only give answers under certain rules; however, with advanced development of deep learning technology since around 2010, the programs learn from given data to build criteria without human input. Medical care requires attention to disease risk assessment, disease diagnosis, treatment selection, and prognosis assessment. However, these factors may be difficult to evaluate due to differences in individual situations. The benefits of medical AI for both patients and medical staff, including radiological technologists, is that it is possible to construct judgment criteria based on a large amount of accumulated patient data and present the optimal treatment method for each individual. Medical treatment is roughly divided into three steps; namely, prevention of disease onset, diagnosis to distinguish people who already have the disease, and treatment to improve the prognosis of patients with a diagnosis. Medical AI can contribute to any of these three steps and is expected to be utilized in all medical fields, following its increasing application in medical systems including medical insurance systems.

In medical images handled by radiological technologists, a series of processes from image capture to diagnosis is the most important use of medical AI. In particular, Japan is rapidly aging, with a corresponding increase in the number of medical images requiring interpretation that is not matched by an increased number of radiologists. Medical AI can directly reduce the workload by helping radiologists to read images; moreover, it and may also prevent and reduce re-imaging and patient exposure dose. In addition, medical AI can be used to educate radiological technologists. It is possible to learn normal and typical medical findings, distinguish imaging findings (panic images) that require an emergency response, and improve image analysis and evaluation. Furthermore, it is possible to improve the imaging technology to provide higher quality medical images, reduce patient exposure dose due to the difference in imaging procedures, and perform more effective dose measurement and dose evaluation in cancer treatment.
We introduce the two latest medical AIs that support the work of radiological technologists in Japan.

Detection support (bone suppression processing)

Bone suppression processing generates an image from which the signals of the

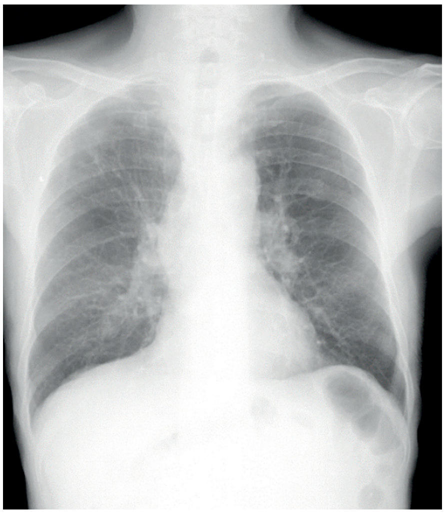

Figure1: Chest X-ray image (original image).

Figure 2: Bone suppression image (BSI).

clavicle and ribs, which are obstacles in the interpretation of chest X-ray images, have been removed. Figures 1 and 2 show a chest radiograph and bone suppression image (BSI), respectively. Unlike energy subtraction, the feature is that the image of the bone signal is removed from the single plain X-ray image of the chest taken by a normal system using the AI image analysis. The doctors who interpret the images can reduce the possibility of missing the lesion hidden in the bone by alternately checking the original and BSI. In the bone recognition process, the estimated value obtained from bone structure data collected from significant chest X-ray image data and the estimated result of the bone structure measured from the target chest X-ray image are used to extract the detailed structure. In bone signal attenuation, the signal component of the bone is estimated from the recognized bone candidate to perform attenuation. In this process, only signal changes due to the bone are accurately estimated and attenuated, leaving the signals of fine structures such as abnormal shadows and blood vessels overlapping the bone, improving the lesion visibility and reading efficiency.

We performed receiver operating characteristic (ROC) analysis on the accuracy of tuberculosis (TB) diagnosis from BSI by nine Vietnamese radiologists using chest X-ray images of 325 cases. We observed significant differences between the three radiologists specializing in areas other than the chest. The area under the ROC curve (AUC) without and with BSI were 0.882 and 0.933, respectively. This method is very useful for educating radiologists or radiological technologists. Furthermore, the method also improves the image capturing ability of radiological technologists and provides high-quality images that can contribute to early TB diagnosis. In addition, identification of abnormal findings at the time of imaging by radiological technologists may allow them to suggest additional imaging to doctors or examinations with another modality while the patient is at the hospital without returning home. This method is also expected to allow diagnosis and treatment.

AI to improve the examination workflow for radiological technologists

The increasing awareness of medical safety underscores the necessity for exposure dose management systems that can centrally manage X-ray irradiation information such as exposure dose and imaging protocols for individual patients base on X-ray imaging, computed tomography (CT), and other diagnostic imaging devices. By linking with the radiation work management support system, various radiation inspection data can be visualized to support both the analysis and optimization of medical exposure. In addition to modalities with high exposure such as CT, to reduce exposure doses due to general radiography with the highest frequency of radiography, we developed AI-based software to automatically detect imaging failure needed re-imaging. These applications include the automatic detection of lung field defects (Fig. 3) and blurring in chest X-ray images, which are frequently photographed, and AI, which automatically detects poor positioning of the knee joint (Fig. 4), which may cause image defects. Software that

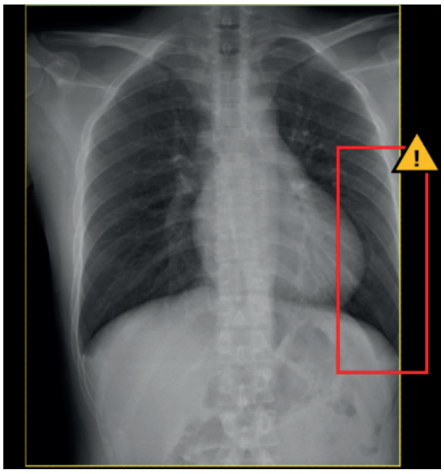

Figure 3: Example of the detection of a lung field defect.

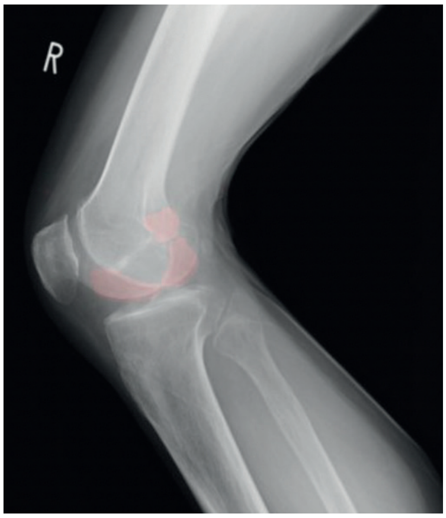

Figure 4: Example of imaging failure (external rotation) and the judgment area (pink).

automatically detects these various types of imaging failure is expected to provide educational support to reduce imaging failure and improve technology. The use of this AI software allows the automatic identification of the images that may be missed; moreover, by visualizing the number of times, it is possible to identify which technique results in the most missed images for individual radiological technologists. It is also possible to carry out targeted education. Furthermore, by creating a graph that is classified according to the cause of re-imaging combined with an environment in which the cause of the loss can be analyzed along with the failed image, it is possible to continuously examine issues, study measures to prevent loss, improve activities, and improve effectiveness. It can be expected to support a measure to reduce re-imaging. As a result, the patient burden is reduced by shortening the imaging time, the efficiency of imaging work is improved, and the inspection time for each imaging device and the operating rate of each imaging room are visualized to allow the development of optimal placement plans for each device and radiological technologist. It will also support the comprehensive management of medical and radiation services.

Elevating patient care in nuclear medicine & molecular imaging using Artificial Intelligence (AI)

By Angela Meadows, United Kingdom

Angela Meadows
Angela currently works with Alliance Medical in the UK and is responsible for managing the NHS imaging service partnerships at the Preston PET-CT Centre and the MRI service at Westmorland General Hospital.

Angela has worked in imaging service management for over 13 years, managing PET CT and MRI/CT imaging partnerships in both the public and private sectors.

Angela's specific interests are in PET CT, research, paediatric NM imaging and MRI safety.

Angela is currently chair for the Nuclear Medicine and Molecular Imaging Advisory Group for the Society & College of Radiographers in the UK.

Introduction

AS radiographers and radiological technologists unite around the world on November 8, 2020 for World Radiography Day, there will be reflection upon a year like no other. 2020 has been a pivotal year globally, as we have had to adapt to a worldwide pandemic. We have had to adapt rapidly, and embrace communication technologies we may not otherwise have been comfortable with. For many, video calling/conferencing is inconsequential now, its second nature, but step back to 2019 and look forward and we could not have imagined the way in which we communicate now, and how we have adapted as we socially distance as a means of global pandemic protection.

Similarly, when we look at the term Artificial Intelligence (AI) we can conger up images from films like AI, and the Matrix. We could imagine imaging technology which would require little human contact, machine learning technologies, computer algorithms, data, data and more data.

However, let's stop and take a look at Nuclear Medicine (NM) & Molecular Imaging (MI), its advancements and AI technology examples that have been in use for many years, and consider the benefits of AI in elevating patient care.

Background

What's does the term Artificial Intelligence (AI) mean?

"An area of study concerned with making computers copy intelligent human behaviour"[1]

As many AI definitions similarly suggest, AI is the ability of a system to be able to copy or simulate intelligent human behaviour or performance. However, there are two further key phrases to be aware of along with AI, these are Machine Learning and Deep Learning (See Fig 1).

Machine Learning is a subcategory of Artificial Intelligence that uses statistical learning algorithms to build systems that have the ability to automatically learn and improve from experiences without being explicitly programmed. We use these daily in search engines such as google and yahoo or voice assistants such as 'Siri' and 'Alexa'.[2]

Deep Learning however is a machine learning technique that is inspired by the

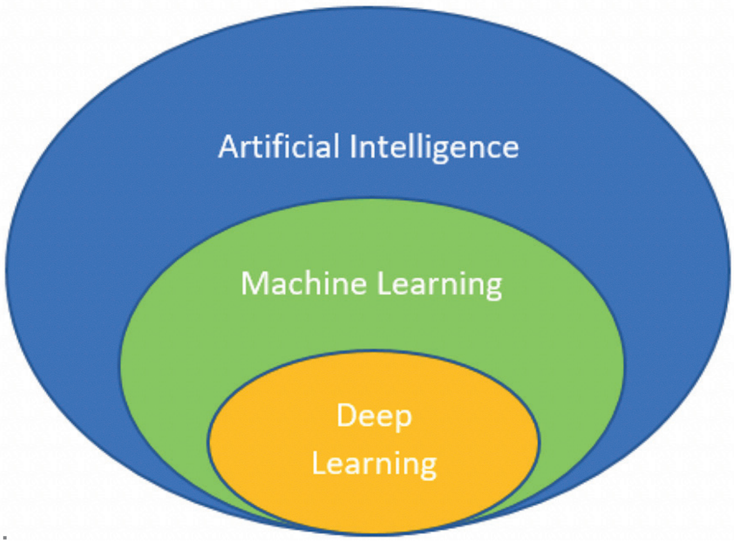

Figure 1.

way a human brain filters information, it is basically learning from examples. It helps a computer model, to filter and input data through layers to predict and classify information. Subsequently, deep learning processes information in a similar manner to the human brain, it is the kind of technology used in driverless vehicles.[2]

In NM & MI the very essence of our role as a radiographer or RT is to work with ever developing complex imaging technologies, technologies which have evolved over the years, which take complex computer reconstructions and algorithms, which would typically have been manipulated by the radiographer to now automate them for the radiographer, thus allowing the radiographer, to focus on the human patient care aspects of the imaging examination, aspects such as physical and psychological wellbeing. When considering patient care and management it is simpler to consider the imaging procedure split into three elements, preparation, during and post imaging procedure. When we consider the imaging procedure broken down in this manner there are multiple points at which AI can feature to enhance the procedure and assist radiographers & RT's to ensure they can achieve the optimal image quality and patient care they strive for.

In NM and MI procedures such as PET-CT, there is an inherent complexity to image acquisition, from a static bone scan acquiring thousands of image counts per second, to more complex hybrid technologies which integrate two separate scanning systems such as PET with CT and SPECT with CT. Over the decades there are countless examples of where computers have evolved with imaging technology advancements, to allow faster image processing, manage greater volumes of data and present image detail and resolution better than ever before. We have now moved into a time where imaging platforms present an intuitive approach for their users blurring the lines between the radiographer and the technology to work as one.

In this article I wish to highlight some current examples of AI in NM & MI practice and consider how we work with AI technologies to elevate patient care in this field.

AI in NM & MI - Current & advancing technology

Some of the first examples of AI in practice which remain in NM, involve the use automatic organ segmentation techniques. Computer based segmentation techniques allow Radiographers and RT's to review and quantify image data presented as regions of interest (ROI's), this process provides an analysis of regions and sub regions. Some of the first examples of quantitative segmentation imaging are found in Tc99m DMSA renal imaging studies, which not only assess the size and location of the kidneys but more importantly the relative renal function to determine if renal scarring may be present. In addition to Tc99m DMSA, more complex segmentation techniques can be used in lung SPECT CT, to assist in the analysis of Pulmonary Embolism. Both of these techniques have evolved over recent years and are good examples of AI in practice, as in both instances, automated analysis takes place using an applied computer algorithm which automatically assumes the ROI for the Radiographer, thus freeing up more time for the Radiographer to be with the patient post procedure.

AI throughout the NM & MI imaging procedure

I previously explained that when we consider patient care and management it is simpler to consider the imaging procedure split into three elements, preparation, during and post imaging procedure. Taking the procedure as three elements we have examples of how AI can elevate patient care.

AI in NM & MI - Imaging preparation

Often a significant challenge in the preparation and scheduling of an examination, is ensuring a concise yet appropriate medical history is detailed on the imaging referral. If this information is not provided clearly by the referring clinician, manually accessing this necessary information can prove difficult, particularly for imaging services which cover a large geographical area such as PET-CT, as referring hospitals do not necessarily share the same databases for patient information. It is essential therefore that the Reporting Clinician is comfortable that the imaging procedure requested is appropriate to the patients clinical need, thus ensuring no unnecessary radiation procedure takes place. Much research is ongoing in the field of algorithmic information extraction and what is also known as the data interoperability standards such as Fast Healthcare Interoperability Resources (FHIR).[3,4] Such systems we hope will become gradually available in the clinical setting with concise case specific dashboards becoming accessible with time. Improved access to data, means more timely approval for the imaging procedure and faster imaging results are made available for the referring clinician.

Following the scheduling of an NM or MI imaging procedure, one of the necessary checks is to ensure all measures are employed so that patients do not 'Fail to Attend' (FTA) their imaging appointment without notice. This is particularly important in the field of NM & MI as tracer availability can be limited, is subject to decay and there are of course the associated costs and wasted vital appointments which could occur. Simple machine learning algorithms can be employed to a database which can consider and review patient records for those which FTA. Using AI techniques of this nature, which can consider imaging procedure type, age and sociodemographic data, this may assist in pinpointing trends for such FTA cases, allowing preemptive analysis and reminder telephone calls or text message for the patient appointments.[5]

AI in NM & MI - during the imaging procedure

When considering AI in the NM & MI Imaging procedure, there are many different examples which could be considered. Let's take key examples for SPECT CT and PET CT as complex hybrid technologies, these use AI to enhance imaging capabilities and improve the patient experience.

Hybrid technologies use two independent systems i.e. PET with CT or SPECT with CT and integrate the images by image fusion. These systems are processing huge volumes of data and are making use of machine learning (ML). Recent advancements in research suggest considerable technical improvements in the near future for such technologies.[6] In NM & PET CT, attenuation maps and scatter correction remain a key discussion point for AI groups.

I previously explained that AI now supports an intuitive approach on the imaging platform, particularly when it comes to day to day running of the systems. A good example is the ongoing monitoring of imaging systems in the background by the Original Engineering Manufacturer. Often issues are flagged before they are even apparent to the operator, as flags are raised to engineers, this allows them to arrange planned maintenance and address potential technology issues which would otherwise disrupt service without warning. Dose optimisation is also a significant focus across all NM & MI imaging, with again hybrid systems using ML technology which is capable of personalising the scan field of view based on anatomy. Such systems can use single flowing patient scanning table movements to image patients top to toe in one flowing movement rather than section by section image acquisitions, this enables improved dose optimisation techniques and can often reduce the CT dose further.

As previously described, technologies in NM & MI use not only AI & ML technologies but also deep learning (DL). DL requires complex algorithms for more complicated procedures such as simulation respiratory gating for example. In 90% of PET-CT oncology cases, disease is located in the chest or abdomen.[7] These areas are subject to respiratory motion, which can displace organs and lesions by a range of 5mm to 30mm, blurring images and reducing diagnostic confidence.[8] And without respiratory gating, 40% of lung lesions may even go undetected.[9] The use of DL technology in these cases means that no additional scan time, count acquisitions or complex equipment needs to be added as the DL algorithms are applied to the images and in turn reduce the appearance of respiratory motion, delineating small nodules otherwise unclear. It is important however to make clear that the use of AI does not diminish the requirement for the Radiographer or RT to fully understand complexities of the imaging technologies that they operate.

AI in NM & MI - Post imaging procedure

There are many reconstruction and post processing algorithms which can be applied in NM and MI. It is important that the Radiographer, RT and Reporting Clinician all understand the strengths and limitations of such algorithms and have a sound knowledge of post procedure image manipulation and its pitfalls. An algorithm can only be as smart as the data provided, so it is essential that this is fully understood by the operator.

When considering image reporting, predication and response to therapies are areas where quantitative analysis can prove a powerful tool if used correctly. Assuming that NM and MI imaging scans performed pre and post treatment, are performed with consistency and accuracy, the resulting image quantification using standardised uptake values (SUV) will prove a reliable tool to measure and make assessment for treatment therapy response in oncology cases. This will allow the referrer to confidently adapt treatment regimes for their patients based on imaging findings.

Finally, when considering the generation of the imaging report, this is also subject AI techniques. Again, techniques which have been recognised for many years now, such as voice recognition which uses ML technology. This allows for prompt image report generation and distribution direct to the imaging referrer if set up to do so. Slick image reporting techniques are of great importance in the imaging pathway to ensure timely result generation to referring clinicians, which in turn ensures prompt action and more immediate patient care/interaction as a result of the image findings.

Conclusion

This article has provided an overview of the different terms used in AI. This includes the concept of Machine Learning and Deep Learning. This article has also considered the imaging procedure split into three elements, preparation, during and post procedure. When considering the procedure broken down in this manner, there are multiple points at which AI features to enhance the procedure and assist radiographers/RT's, to ensure they can achieve the optimal image quality and patient care they strive for.

It is important however, to also recognise that AI technology has actually been with us for many years. We need to continue to embrace technological advancements as professionals but we must ensure that for optimum integration of AI into the clinical imaging setting, appropriate education of the current and future workforce and the active engagement of radiographers and RT's in AI advancements is essential to ensure the safest and highest standards of patient care.[10]

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Elevating patient care with Artificial Intelligence: An educator's point of view

By Yudthaphon Vichianin, Thailand

IN this year, the World Radiography Day theme is "Elevating Patient Care with Artificial Intelligence". Radiographers are one of the key stakeholders in delivering patient care with artificial intelligence in the fields of radiology, radiation therapy, and nuclear medicine. Recently, a joint statement of the International Society of Radiographers and Radiological Technologists and the European Federation of Radiographer Societies was published on this topic. The joint statement article can be directly accessed at the ISRRT website[1] or on ScienceDirect[2]. The statement suggests that the "radiographers and radiological technologists are the interface between imaging technology and patients." It also indicates the importance that radiographers and radiologic technologists have in the process of AI algorithms testing and validating prior to clinical implementation. As the ISRRT Director of Education, I offer my personal perspective for educators to consider as they prepare their students to deal with the AI era as they become educated AI users of the upcoming technology.

What will educators around the world need to adapt their teaching for radiographer students to prepare to AI in the future?

The joint ISRRT EFRS statement states that before using AI in clinical settings any proposal has to be validated before implementing it in practice. Radiographer and radiological technologist students should be prepared and equipped with an essential skill set during their classwork or in their senior projects the ability to perform systematic approaches in basic research or tools/technology evaluations. In the real situation, the evaluation of the AI prior to clinical practice may be preceded as research projects. The project teams may include physicians, engineers, physicists, radiographers and radiological technologists, statisticians, scientists etc. Working as a team of professionals, the role of radiographers and radiological technologists in the projects may vary from that of image acquisition, data collection, or data analysis. As a result, some basics in statistics, basic research methodology, and research ethics may be required in the students' classwork. For example, at the Department of Radiological Technology, Mahidol University, the third-year students are required to work on the Term Paper I and II (total two credits with in two semesters) for literature reviews in various radiology areas, research methodology and data collection techniques as well as some basic statistics for data analysis in different types of researches. Upon finishing the third year, students are equipped with a broad view on conducting research and would be ready to perform a senior research project under their advisor guidance. The AI techniques commonly employed and published research publications can be used as examples of research methodology to introduce senior project classes to the principles and application of AI technology.

What new subjects will have to be incorporated to have students begin to understand and how is AI technology being used in education in radiography profession?

Since the education program for radiographers and radiological technologists varies from region to region, I would like to outline the topics for educators to consider for incorporating into the program. In order to broadly understand how AI works, some backgrounds in mathematical and statistical modelling techniques related to AI are required beyond the basic courses. Hence, mathematics and statistics classes are considered important core courses in the program. The combination of these subjects is not only beneficial in AI but also important for scientific methodology in general.

Moreover, a large data set is usually required to test the developed mathematical or statistical modelling in AI. As a result, programming and data management skills are also essential skills. Python programming language is one of the most powerful computer languages and greatly used in the AI development process. Also, various tools associated with Python are

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Currently, Yudthaphon is an assistant professor and the program chair of the Master of Sciences in Radiological Technology at the Faculty of Medical Technology, Mahidol University in Bangkok, Thailand.

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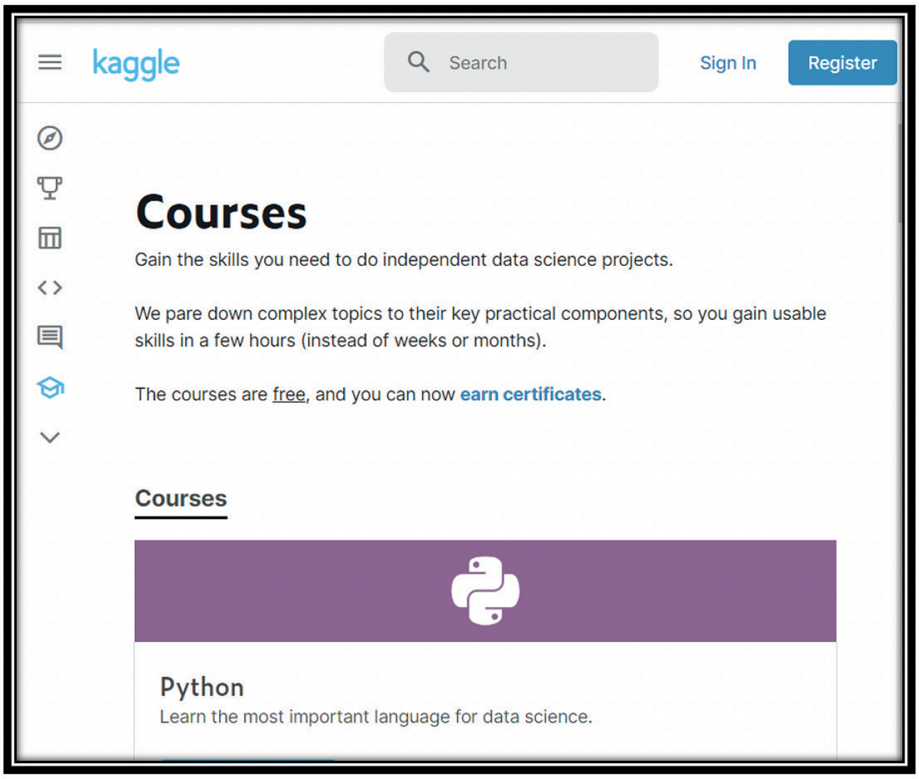
He is highly active in the Thai Society of Radiological Technologists (TSRT) giving numerous training classes in PACS and MIIA certification preparation. He teaches at a number of universities in Thailand as an invited lecturer.

widely available for users and developers. Hence, educators may consider including or adding some programming and data management content into their courses in the curriculum. One great application of AI is Machine Learning (ML) technique. According to the Expertsystem.com[3], ML is an application of artificial intelligence (AI) that equips any system with the ability to automatically learn and improve from experience without being explicitly programmed in advance. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves. This is one of great resources that educators can use in learning assignments and materials in their advanced course work or advanced work assignments. For example, there is a Massive Online Open Course (MOOC) in Data Mining using WEKA software offered by the University of Waikato, New Zealand. It can be accessed via Youtube.com at www.youtube.com/user/WekaMOOC. The "WekaMOOC" offers a wide variety of video as e-Learning that can be a great starting point for students and individuals who are interested in AI. In addition, the "WEKA" open source software[4] is also freely available and ready-to-use with an intuitive graphic user interface. It can be downloaded from www.cs.waikato.ac.nz/ml/weka/. If you want to learn more in depth techniques of machine learning using WEKA, a book titled "DATA MINING: Practical Machine Learning Tools and Techniques"[5] is also available at additional cost.



For a more advance AI technique, deep learning[6] has recently gained huge interest from scientists around the world. In deep learning, a more complexed modelling together with a larger data set is utilized to improve the system ability to deeply experience and make more accurate decisions. Luckily, at Kaggle.com[7] there is a set of free access online courses for anyone who is interested in developing the data science skills. The courses include Python programming, introduction and intermediate level for Machine Learning, data management using SQL (Structure Query Language) both introduction and advance levels, and many more. These are invaluable resources that educators can access and utilize for their classes or use in any radiography and radiological technologist programs. These free online courses are well organized, and more importantly, they can be freely accessed anywhere and anytime upon your convenience.

One of the important roles of radiographers and radiological technologists incorporating AI in our professional practice is patient care. The joint statement of the International Society of Radiographers and Radiological Technologists and the European Federation of Radiographer Societies emphasize the important on the role of radiographers and radiological technologists as clinical decision makers. We should use AI as our support tool, "not a replacement for, clinical judgement and professionally accountable decision making". This reinforces the fact that the AI is an extension to the professional capability.

In my opinion, patient care and communication skills still play a very important role in our professional practice. AI may be utilized as tools such as image enhancement, smart patient scheduling, or improved patient workflows. However, radiographers and radiological technologists are "the interface between imaging technology and patients." At my school, beside the technology related classes the students are also required to take "Patient Care and Radiological Service Management" classes[8] which focused greatly on patient-centered services in clinical practice.

In summary, as an educator myself, I wish that all my colleagues around the world may consider and start empowering their students with essential skills including mathematics and statistics for AI, data management (i.e. SQL), computer programming (i.e. Python). I hope that these examples of available resources and information presented become your starting point to inspire your classes and curriculum development in preparing our next generation students to become great radiographers and radiological technologists in the near future whilst embracing the opportunities of AI in the modern era.

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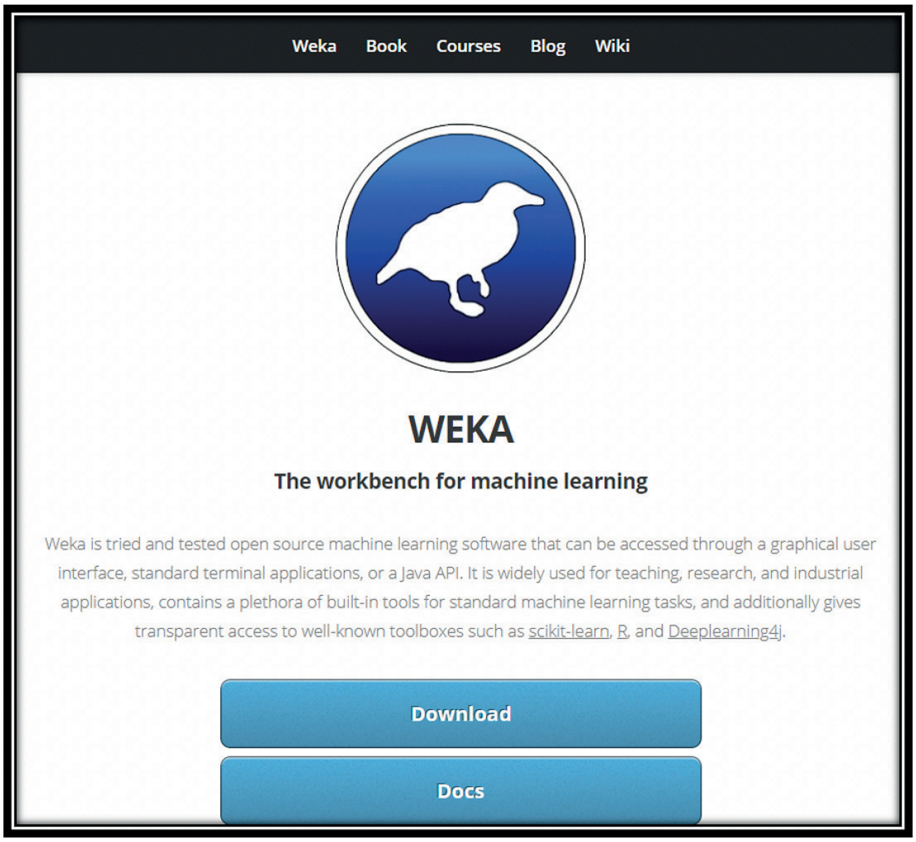

Elevating patient care with Artificial Intelligence

By Denise Choong, Singapore

ARTIFICIAL intelligence (AI), as the name suggests, could be broadly described as the programming of a machine to emulate human-like functioning. Many would associate this with robotics and machine automation and fear that the increasing adoption of such technology could ultimately replace us.

AI in Ultrasound

There are four main types of applications in AI in ultrasound: classification, detection, regression and segmentation.
The most notable applications would be classification with computer-aided diagnosis (CAD) and the detection of lesions. Majority of the developments have been made in breast, thyroid and liver lesion detection based on widely used radiological classification systems such as the BI-RADS scoring for breast lesions (Akkus et al., 2019; Brattain et al., 2018). By recognising echotextural and morphological parameters like shape, margins and acoustic shadowing, AI classification applications can differentiate types of tissues. Detection functions can identify and locate objects of interest such as lesions. Together, they can provide radiologists with a second opinion through suggesting a score based on known features of other similar appearing lesions in the training dataset. This can be particularly useful with indeterminate lesions or when there is wide intra- and inter-observer variability in the scoring to reduce unnecessary false-positive biopsies that can increase health care costs and patient anxiety.

The task of regression allows for continuous output values as opposed to categorical classification and has been used in obstetric scans. Often time due to difficult positioning of the foetus, it is challenging to obtain dimensions in the standard plane. By using AI to determine the standard plane of the foetus to facilitate measurement, the abdominal circumference or 3D ultrasound information of the foetal brain can be effective in estimating gestational age, even when the foetus is not in the optimal scanning position. This can avoid extended scanning times or inaccurate measurements that could lead to possible misdiagnosis (Liu et al, 2019; Brattain et al., 2018).

Segmentation is primarily used to identify structural boundaries of anatomical and pathological tissue. It allows auto delineation of structures which is particularly useful in non-rigid organs such

Table 1: Brief summary of tasks in AI for ultrasound

AI task	Function/Uses	Application
Classification	Differentiate types of tissues into discrete categories	Classification of breast lesions according to BI-RADS classification; Thyroid nodules
Detection	Identifying and localising objects of interest such as tumours and lesions	Locating breast, thyroid and liver lesions
Regression	Estimates continuous values	Estimations of gestational age according to abdominal circumference or 3D images of the foetal brain
Segmentation	Demarcation of structural boundaries	Outlining the ventricles of the heart; developmental anatomy of the infant hip; thyroid nodules

(Akkus et al., 2019; Liu et al, 2019; Brattain et al., 2018; Quader et al., 2017)

Denise Choong

Denise is a senior radiographer at National University Hospital (NUH) from the department of diagnostic imaging. She graduated with a Masters of Science in Ultrasound from University College Dublin (Ireland) and has been working at NUH for 9 years. She performs general, paediatric and vascular ultrasound scans and has a special interest in musculoskeletal (MSK) ultrasound. She currently facilitates the advanced training of juniors in MSK ultrasound. Denise is in charge of the EOS low dose X-ray system at NUH used for dedicated long fil scoliosis and lower limb imaging. She also retains a keen interest in intra-operative radiography.

Denise is the President of the Singapore Society of Radiographers and the Singapore representative of the International Society for Radiographers and Radiological Technologists (ISRRT).

as the heart (Liu et al, 2019). Segmentation can also outline the anatomical structures of an infant hip to facilitate measurements using 3D ultrasound acquisitions (Quader et al., 2017). This presents a solution for less experienced sonographers who may find it challenging to acquire high-quality images with fretful infants.

These tasks may seem similar and are not always mutually exclusive; they are often prerequisites for the other. The brief examples of AI applications in ultrasound mentioned here are by no means exhaustive. Research into its uses continues to expand rapidly to further improve the diagnostic capabilities of ultrasound machines which ideally would translate to better patient care through accurate diagnosis with shorter scanning times and fewer invasive procedures.

AI in the patient journey

While many of these developments have focused on aiding radiologists in diagnosis, AI-powered capabilities can impact patient care at various parts of their patient journey in the imaging department.

Another subset of AI that is often overlooked is planning and automation. With automation in scheduling patients, appointment-based services may see smoother patient traffic. AI-powered analysis of current data can also optimise scheduling and workflow to streamline administrative processes. This can help to minimise patient wait times and provide them with a more seamless and pleasant experience. Furthermore, inefficiencies in scheduling and manpower planning can be a precursor to accumulated workload. Consequently, radiographers often experience large patient loads with skeletal manpower leading to fatigue and increased stress. This could be mitigated with the use of AI in planning, to improve the patient experience and look out for radiographer's wellbeing to ensure they are physically and mentally healthy to care for their patients well.

AI image recognition capabilities can potentially accelerate the training of new sonographers to identify anatomical structures and pathologies. These systems can be programmed to help improve detection of potential lesions in real-time to ensure that scans are performed with good diagnostic confidence regardless of sonographer experience. Improved sensitivity of AI in the future may also confer greater reliability in minimizing missed diagnoses at the point of care. For experienced sonographers, AI could improve imaging workflow by suggesting and modifying the user interface to make relevant tools more accessible, thereby providing diagnostic and decision support. The system could also employ auto-annotation to reduce labelling errors that if gone unnoticed, may drastically impact patient care downstream (Kusta, 2018). In addition, prediction by AI can prioritise worklists by identifying high-risk patients (Matthew, 2019) and prompt further investigation to alert radiographers. As such, patients can receive early intervention to mitigate the risks of deterioration, ensuring that high patient care standards are preserved.

The fact that ultrasound is an operator dependent modality makes the human touch an intrinsic part of any sonographic examination. AI can supplement our pathology detection capabilities and clinical decision making skills but it cannot replace the communication and rapport we establish with our patients during the examination. Furthermore, the required skin exposure of the body for the scan makes our attention to the needs of the patient paramount in providing a professional and comfortable setting for the scan.

Challenges of AI adoption

Despite the exciting promise of various AI capabilities, premature adoption of the technology when the infrastructure and macro-environment are not yet established is risky. As the success of AI is highly dependent on the accessibility of data, having proper governance and data control regulations is vital for the appropriate handling and sharing of such highly sensitive healthcare data.

The data itself needs to be processed appropriately before it can be used. With a large mix of structured (largely quantitative) and unstructured (medical images, free text clinical reports) data scattered over many locations, the challenge for AI developers is to reliably and accurately extract and produce 'clean' data in a recognisable format for the system. Furthermore, at the expense of efficient machine learning predictions, there may be reader bias of the predicted findings which can result in reinforcement of findings that may be false.

Another common concern in AI-based CAD is that it is unable to explain how it derives at its decision. The processing 'black box' introduces ethical complications with regard to whether the manufacturer or radiologist should be held responsible in the event of a misdiagnosis. Such ethical and legal conundrums need to be resolved to implement AI safely with proper governance (Ho et al. 2019).

Singapore has taken a cautious stance, starting with emphasis on supporting the infrastructure for AI. In addition to developing and augmenting expertise locally, a model AI governance framework was established to safeguard against the misuse of AI. It includes guidelines on how to address such ethical and governance issues including determining the level of human involvement, ensuring proper internal governance through appropriate standard operating procedures and training of staff. The need for transparency and fairness in AI decision making is also highlighted (IMDA, 2020).

Conclusion

Although there are many issues that still need to be resolved regarding the implementation of AI in the healthcare system, the abundant research to date has shown great potential, particularly in radiology. The systems are complementary to our radiographic practice to enhance diagnostic capabilities, but it definitely cannot replace the radiographer's human touch and the need for patient care. With the advancement of technology, radiographers need to be prepared to receive the advent of AI. With greater awareness of research in AI, its potential pitfalls and perhaps a basic understanding of how AI works, we will be better equipped to utilise the systems as their prototypes are rolled out.

Finally, it is important to remember that patient care not only revolves around the act of care itself but also encompasses being responsible, knowledgeable and

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Artificial Intelligence (AI) in radiation oncology, from perspective of a radiation therapy manager

By Jo Page, Australia

Jo Page
Jo is currently the Director of Radiation Therapy in the Radiation Oncology Department at the Chris O'Brien Lifehouse (COBLH), in Sydney Australia.

Jo's role includes overseeing all aspects of running a busy Radiation Oncology Department, the management of a staff of 46 radiation therapists, and is part of the management team, which includes all the core professions, of the department.

COBLH is a not-for-profit integrated cancer treatment centre and hospital, and Jo is also part of the Senior Leadership Team for the organisation.

Jo has been a Board Member and Past President of the Australian Society of Medical Imaging and Radiation Therapy (ASMIRT) and is currently the ASMIRT Representative on the ISRRT Council.

MY first thoughts when preparing to write this article were of course "What is Artificial Intelligence? So, as we all do, I went to a search engine and asked that question, and of the 837,000,000 answers I went with Wikipedia, for no reason except that it seemed to be the simplest yet most relevant description pertaining to the subject of this article.

> *Artificial intelligence, sometimes called machine intelligence, is intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals.* Wikipedia

How does this relate to radiation therapy, how does it improve what we do, does it make us a more efficient profession, but most importantly does it distract or takeaway from the most important area of our profession which is patient care?

Firstly, I will outline some of the ways that AI tools are used in radiation therapy. I feel it is important to note that these are my interpretations of their uses, not all will agree, and of course there are other areas that some may consider are sources of AI in our profession.

As we know, the aim of any patient's course of radiation therapy is to deliver the necessary dose to the tumour, with as low as possible dose to surrounding tissues and organs at risk (OAR), with the end-goal of maximising tumour kill while at the same time reducing toxicity to the patient. Treatment Planning and the use of Treatment Planning Systems (TPS) in radiation therapy has evolved from 2D hand-drawn planning, to conformal 3D forward planning (with the introduction of use of CT scanning), to 4D inverse planning commonly using Intensity Modulated Radiation Therapy (IMRT) and Volumetric Arc Therapy (VMAT). Inverse planning uses information based on protocols with certain objectives and constraints. The current iteration in a TPS is where we have seen the increasing use of AI. Knowledge Based Planning (KBP) uses a database of previous treatment plans to create a predictive model for different treatment sites. To use KBP each department uses their previous treatment plans to create their own model, which can be extremely time consuming and sometimes subjective passage of work. Departments must ensure that previous plans adhere to their current evidence-based protocols, which will produce a model that is applicable to their existing practice.

As these iterations of treatment planning have evolved there has been an emphasis on improved treatment quality, safety and efficiency within departments. It is imperative for patients to begin their course of treatment with as little delay as possible, and KBP planning is proving to be an efficient method of achieving this.

For a treatment plan to be generated it requires tumour volumes and structures to be contoured from a CT image dataset. As treatment techniques have evolved requiring higher doses to the tumour, complete and accurate tumour volume and structure delineation is required. This process is time-consuming and can be affected by inter-observer variation. To improve this contouring process, Atlas Based Auto-segmentation (ABAS) software has been developed and incorporated into Treatment Planning Systems to automatically contour OAR volumes. The process uses the knowledge of prior image sets with labelled structures. The basis of this requires the generation of an atlas of patient contours into a library with the relevant structures then aligned and deformed to the anatomical structures of the treatment patient.

One of the more recent advances in radiation therapy using AI, is Adaptive Radiation Therapy (ART). "ART is a radiation therapy process where treatment is adapted to account for internal anatomical changes. Some organs in the body can change in size and shape over the days and weeks during a course of treatment. The aim of ART is to account for these changes and deliver the radiation dose to the tumour as accurately as possible." (Peter MacCallum Cancer Centre, n.d.).

The process of ART is to view the day of treatment imaging, access the patients diagnostic imaging, create AI contours, calculate the dose for the scheduled plan on that day's anatomy, create an AI driven adapted treatment plan, evaluate, check plan and deliver.

The question being asked is does the use of these AI tools elevate patient care in the radiation oncology arena? The answer is positive of course, as anything that increases patient survival and/or improves their time being cancer free, without long-term side effects and good quality of life, is the final goal. As systems such as ART are improved and become more efficient, they will become mainstream. However, it is often difficult to implement such systems in a busy radiation therapy department if it has a detrimental effect on the patient workflow. In my own department, the implementation of KBP has improved efficiencies in the planning process, which transpires to patients starting their treatment earlier, and I am sure this is the case in most departments that have KBP.

It is important to remember that all systems such as KBP and ABAS have a human element involved in their design and implementation for individual departments. KBP models are designed using plans previously based on departmental protocols. The same applies to the development of an Atlas, which relies on contouring done manually, whilst by well qualified professionals, but who none the less may have different interpretations of the same image.

There is no doubt about the rigidity and strict quality controls that are involved in any new product development, however any tools that we use are only as good the decision-making processes of those involved, which can be highly subjective and involve, to some extent, a value judgement. As medical radiation practitioners working in the highly emotive area of radiation oncology we must never forget the importance of the patient and their needs both physically and mentally. Technically we must offer the best care possible, but we must never overlook the importance of the individuals that are under our care, whom, to some point, are putting their lives in our hands.

The Australian Society of Medical Imaging and Radiation Therapy has introduced an AI professional working group, that will shortly produce guidelines around the use of Artificial Intelligent tools in the workplace.

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Clinical Evaluation of Commercial Atlas-Based Auto-Segmentation in the Head and Neck Region. Hyothaek Lee,† Eungman Lee,† Nalee Kim, Joo ho Kim, Kwangwoo Park, Ho Lee, Jaehee Chun, Jae-ik Shin, Jee Suk Chang,* and Jin Sung Kim*

Ethos therapy redefines personalized cancer care. An Adaptive Intelligence™ solution, www.varian.com/en-au/products/adaptive-therapy/ethos:

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informed radiographers to remain indispensable in elevating patient care.

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Artificial Intelligence and imaging informatics

By Alexander Peck, United Kingdom

Alexander Peck

Alexander Peck is a Superintendent Radiographer and Chartered IT Professional based in London, UK.

He is the current Chair of the Society & College of Radiographers IM+T Advisory Group, Communications Lead for the British Institute of Radiology and past Vice President for Informatics of the UK Radiological Congress.

He is renowned for his extensive international voluntary educational work in the imaging informatics field, from devising and running the UK's only national non-profit informatics training for PACS Teams, Radiology System Managers and Allied Health Professionals over the past decade to training thousands of radiographers on the fundamentals of the speciality.

Alexander lectures widely in universities and at medical conferences and is also the author of a number of texts in the global 'Clark's' radiology series of books, including Clark's PACS, RIS & Imaging Informatics (pacsbook.com).

WITHIN the Medical Diagnostic Directorate, Imaging Informatics (the use of computers in and to support patient care) is most likely the place where many individuals believe AI is already highly integrated and prevalent in daily work. While it is true that many countries are investing millions of dollars into AI research the view from the offices of PACS Managers and other professionals in the speciality around the world is at the moment more inconclusive on the true distribution currently available.

Presently, in the field of Informatics, common implementations of true AI are fairly difficult to come by. Many currently used systems touted as containing AI (for example some breast nodule detection and alerting systems, orthopaedic bone recognition and labelling algorithms or common chest pathology classification add-ons to PACS) actually be better labelled Computer Aided Detection systems, and don't truly have the capacity to 'learn' and adapt as they ingest more studies. There is nothing wrong with this, indeed it is a similar story with 'self-driving cars' such as Tesla Motor's 'autopilot' feature across its range still requiring a significant degree of human control with minimal on-board learning and adaption features. This effect of potentially over describing medical software features as 'AI' (for either marketing or 'hype') at present has the potential to have the effect of reducing the perceived value of the true AI systems, which as many others have described have the power to greatly affect patient care and simply the workload burden on Radiographers in the (potentially near) future.

Numerous positive examples of the AI technologies finding well lauded and highly beneficial usage have been demonstrated outside of healthcare - for example utility supply companies (such as water, fuel or gas suppliers) are able to use Artificial Intelligence networks to process signals from IOT (Internet of Things) sensors embedded under pavements, roads and in control centres to determine the extent and location of leaking water or gas pipes - the system simply 'listens' to normal background noises and activities, 'learning' what is normal and what may indicate an abnormality. A leak or break can then be flagged up in real-time to engineers. This leads to the question: Why is AI not more widely utilised within healthcare presently? For example, the modelling of blood flow is remarkably similar to some fluids frequently monitored by the utility companies, particularly when examining the turbulent nature of flow within the heart versus the turbulent flow of water in a pump value. 4D, motion based imaging is already available in research settings and many dedicated Radiographers have examined ways in which more subtle appearances on Cardiac MR and Cardiac Fusion studies can be highlighted for closer analysis - preventing minor details form being overlooked by Reporting personnel. These types of imaging being available provide the perfect raw data for an AI technology to work with, likewise additional sensors could be developed to form part of existing therapies such as implantable cardiac devices to provide a data source for detecting cardiac problems 'at source' and in real-time rather than requiring an out-patient or hospital intervention. The approach to normalising AI in healthcare seems to need an adjunct though and this may be the patient themselves: could AI be utilised along with the data provided by patient worn sensors to perhaps provide those same Cardiac Radiographers more contextual data from their patients? Fluctuations of blood pressure, blood biomarker status and user input activity (exercise etc.) classifications would complement the data collected by sensors to allow for more detailed analysis and a 'wider picture' view.

This however leads to the perennial question of accountability and liability. Returning to 'self-driving' motor vehicles, many justifications around the world have yet to rule definitively (due to lack of test cases) on who would be responsible for a fatal car accident involving a vehicle under AI control – the 'supervisor'/ driver, the software developer or the car manufacturer? These same questions will be applied to any new AI implementation within healthcare – an historically far more litigiously contentious environment. The use of AI has inherent legal implications given the underlying loss of human control, but also in the provision of training data: all AI algorithms must first work on a large training dataset in order to become 'intelligent'. Where does this dataset come from? Patients may not consent to the use of existing medical data for this kind of 'machine training' purposes. In addition, there are also ethical questions: could AI be 'trusted' to automatically prioritise cases on a busy reporting worklist depending on what the AI believes may be demonstrated (or not) as the pathology even if this were to delay other patient care or change a treatment pathway? On the other hand, as reporting backlogs continue to rise around the world, the implementation of AI in worklist control could even take over the entire function of reporting less significant caseloads and allow reporting Radiographers to become more focussed on developing speciality reporting services (CTs etc.), presenting an opportunity to increase patient care if implemented and controlled well.

Another such innovation which could be most likely benefit from the development of AI assistive technologies are Radiographer Led Discharges. This process, which occurs in limited extents around the world, is where a radiographer is responsible for the majority of the patients entire pathway through the healthcare service and is likely to be successful in bony trauma situations where referrals are comparatively simple (patient history is available, the clinical context is known, the singular clinical questions being generally: is there a fracture? etc.), imaging typically 'while-you-wait' and reporting, evaluation or commenting protocols are in place anyway to support immediate medical care to any detected abnormality. Adding the further final step of dispatching the patient home (with follow-up clinic appointments if for instance a fracture was detected and treated) is not revolutionary, but requires highly skilled and specially trained and authorised radiographers and a professionally developed service, making this is less common process than it could otherwise be. Allowing AI applications to take care of some elements of this journey (notably if it were able to 'clear' non-afflicted patients reliably and allow for clinical time to be better preserved for those with injuries) would be innovative and allow for radiographers to focus more on the human aspects of the interactions rather than the time consuming reviews, paper trails and referrals which cause the phenomenon known as 'imaging drag' (the delays caused to a standard patient journey due to administrative processes or non-optimised uses of technology) today.

Other areas of application of AI which would benefit the radiology department are more mundane, and most likely to be thought of as less exciting than some of the other articles in this special edition! One such example is the use of AI in examination justification (vetting) or protocolling (assigning a study to the correct speciality, area or modality). Countless hours of radiology department time are taken by these few crucial steps found in every imaging examination request and yet very little has historically been offered to automate or streamline these. Allowing AI to take over the vetting and protocolling roles would allow for staff time to be more focussed on imaging and the actual physical patient-care elements, but with the topic being so unremarkable it is unlikely to attract funding or researchers into progressing it – a key prerequisite to development.

Of course we have to ask ourselves, as with many IT based technologies, is AI a solution looking for a problem? Presently, all AI based or machine learning algorithms must only be used as a 'diagnostic aid' - final interpretation being performed by a licensed healthcare practitioner with the appropriate training. Are we simply looking for applications of this fascinating technology that really will still need a human?

Overall, when considering these few examples, AI is at present underused and primarily in place for computer aided diagnosis purposes. Radiographers promoting AI to completely handle automated routine and time-consuming tasks will be the 'next big step' in the evolution of the technology - an evolution which will no doubt be required to overcome the legal hurdles posed in our various jurisdictions around the world. Being very much in its infancy, Artificial Intelligence has the potential to change the way radiology works, but likewise it has the potential to be a large consumer of financial resources if radiographers working on the frontline are left out of the decision making and scoping processes.

ALARA AI

By Noeska Smit, Netherlands

Noeska Smit

Noeska Smit has been an Associate Professor in Medical Visualization at the University of Bergen, Norway, since 2017. She is also affiliated to the Mohn Medical Imaging and Visualization (MMIV) centre as a senior researcher.

Currently, she is researching novel interactive visualization approaches for improved exploration, analysis, and communication of multimodal medical imaging data.

Noeska is a licensed radiographer with three years of practical experience in the Netherlands at the MCRZ hospital in Rotterdam, the Netherlands.

She completed her studies in Computer Science at the Delft University of Technology, specializing in Computer Graphics and Visualization in 2012. In 2016, she obtained her PhD in medical visualization at the same institute in collaboration with the Anatomy and Embryology department at the LUMC in Leiden. Her PhD research project, entitled 'The Virtual Surgical Pelvis' resulted in a detailed virtual 3D model of the pelvic area from heterogeneous anatomical data that is used in education and has potential for pre-operative surgical planning.

WHEN I was still actively working as a radiographer in the Netherlands, about 15 years ago, I experienced the beginning of the transition from developing X-rays on film to fully digital systems. This transition brought drastic changes to the workflow. Where I used to go to the radiologist to discuss images film-in-hand as needed, this changed to calling the radiologist and asking him or her to bring up the images. We went from charming hand-written, at times in illegible doctors handwriting, paper X-ray requests to a fully digital system. In addition, the devices became more sophisticated. Where before I was always thinking about picking the optimal film size, kilovoltage (kV), and milliampere per second (mAs), now it became possible to pick X-ray foot' from a protocol database and maybe make small adjustments from there. Of course, this could reduce the amount of human errors, such as incorrectly entering the wrong kV and mAs, but it also may increase error if a radiographer takes incorrectly recommended values without further thought.

This was also the time I quit my job as a radiographer. I realized I was more interested in 3D CT reconstructions than in helping orthopedic patients on the table. I really wanted to dive deeper into these more technology-focused aspects.

Another challenge that made my life as a radiographer difficult is that I had a hard time not continuing to think about the more severe cases I saw on the job in my private life. I went on to study computer science and specialized in computer graphics and visualization. I guess this sounds like a direction as far away from patient care as possible, but while my daily work life has changed a lot, my main goal is still the same: I want to work on things that can help people. In medical visualization research, I work on developing systems that make visual representations of medical imaging data that help people carry out their tasks more effectively for data exploration, analysis, or communication purposes.

The advent of artificial intelligence (AI) may lead to another turning point in the workflow for radiographers. As previously with the transition from x-ray films to digital solutions, AI-based software algorithms may play a larger role in the future in handling the technical aspects of the job, for example improving image quality or automatically indicating potential pathology. In AI, typically software is trained to perform certain tasks based on a learning procedure. For example, the computer takes hundreds of labeled CT-scans and can then attempt to automatically label an unseen CT-scan, based on what it has seen in the other labeled scans. While these days artificial intelligence is sometimes seen as some sort of magical solution that can solve almost everything, I would argue it cannot and for the moment should be critically examined before accepting it into radiographer workflows. There are serious issues with many artificial intelligence-based solutions and I believe radiographers can play a key role in responsible use of AI.

The first key issue with AI-based solutions is that they operate as a so called 'black box'. This means that it is not possible to see how the software came to its decision. To follow up on the previous labeled CT example, AI will be able to provide the labels, and potentially even how sure it is of these labels, but it cannot tell you how it did it. This may lead to strange situations, for example, closer examination of an algorithm trained to identify pictures of airplanes revealed that it actually identified these pictures only by looking for blue sky in a photo. For medical imaging data, we should make sure that AI-based solutions are trustworthy. It is very hard to trust in techniques when it is completely unclear how they come to their decisions.

Another key issue is that AI-based algorithms can make mistakes. Incorrect results may be alright when it comes to identifying pictures of cats or gender-swapping selfies but are unacceptable when it comes to algorithms proposing diagnostic or treatment advice. A radiographer has the skillset to check the original image data against AI-enhanced image data to ensure that no mistakes are made. Coming back to the CT labeling example, incorrectly placed labels could be spotted and corrected by a radiographer. For AI-enhanced increased resolution, a radiographer could check that important pathology is not de-emphasized. Here, the technical expertise and experience that a radiographer has is valuable to verify correctness.

In my previous medical visualization research, we developed a technique that can visualize autonomic nerve regions in MRI scans for pre-operative planning, while these nerve regions are not visible in MRI originally. The goal here was to reduce severe surgical side-effects that arise from nerve damage. A surgeon could take this information into account in his or her planning, but the goal was never to let the computer do the planning or even the surgery. In this case, people are using computers to support decision making. We combine what people are best at with what computers are good at. Computer-assisted decision support is by no means new, and airplane pilots have relied on computer-guided controls for years. Key to the success of such approaches is to combine human expertise with computer support. In a way, I think radiographers could have a similar role with AI. We could combine what radiographers are best at with AI-based solutions for the more tedious parts of the job. These AI-based solutions can only be brought in if patient safety and treatment quality can be guaranteed.

The previously mentioned limitations of AI are under active research for the moment, trying to improve algorithm performance, as well as opening the black box by so-called explainable AI. If artificial intelligence becomes good enough at some point to take over some of the technical aspects of a radiographers job, this is also an opportunity for improved focus on patient care. If less time needs to be spent tweaking imaging parameters and acquisition protocols, this may lead to more time that can be spent making sure the patient has the best possible experience and undivided attention. Still I don't think we are quite there yet with the current state of AI and for the moment am reminded of the guiding principle for radioprotection: As Low As Reasonably Achievable (ALARA). I propose we keep the use of AI in radiographer workflow as low as reasonably achievable as long as key critical issues are not addressed. The profession of radiography has a rich combined expertise in technology and patient care. As such, I believe radiographers are excellently positioned to be critical of newly introduced AI-based solutions and responsible for ensuring that the best possible patient care is provided.

Breast Imaging and Artificial Intelligence

By Jill Schultz, USA

Jill Schultz

Jill holds a Bachelor's degree in Business Management from the University of Sioux Falls, SD and is a radiologic technology program graduate. ARRT professional certifications include radiology, mammography, quality management and is a certified navigator in breast management through the NCoBC.

Jill is the current Breast Program Quality and Accreditation Coordinator at Avera in Sioux Falls. Her professional experience includes managing/directing radiology, mammography, radiation therapy, breast surgeon clinic and various aspects of development of breast programs. She has led multiple types of breast and oncology program accreditation efforts over the years as well as project and program management, safety and service excellence. She has served on professional local, state and national committees and boards with SROA, NCoBC, ASRT, ARRT, SDSRT, grant committees, and volunteer Haiti mission work since 2012, helping to start a breast program in Western Haiti. She has provided numerous breast health public and professional educational presentations and training for new mammographers and authored several breast health articles/ documents.

I SUSPECT I am not alone when saying I have had mixed feelings about Artificial Intelligence and mammography over the years. The term 'artificial intelligence' can seem somewhat unconventional or futuristic. I often think of 'artificial intelligence' as being referred to in various action-filled science fiction movies. Only a couple years ago, I recall hearing radiologists talk about Artificial Intelligence (AI) in a general manner as they wondered where the future of AI would take them. Their discussion included wondering if AI would replace them in the future, while surpassing their human abilities.
It is that type of fear-provoking conversations that makes me think the term 'artificial intelligence' is somewhat unfortunate. Perhaps it would be met with less fear or resistance if this type of technology was referred to as 'intelligent decision assistance' or something that sounds more helpful. After all, the goal of AI is to improve patient care by increasing accuracy and providing efficiencies. It is technology that can assist the overall imaging process and it directly helps radiologists, which in turn ultimately benefits the patients we serve.

Forget the fear- reality reveals there are very practical roles for AI in breast imaging. Whether you realize it or not, artificial intelligence has been an important part of breast imaging for a number of years.

Mammography

With mammography, AI based computer aided detection (CAD) has been an integral part of breast imaging for 20 years. Computer aided detection, CAD research started in the mid 80's and the first mammography CAD was available for purchase in 1998. CAD technology has continued to change and greatly improve its performance over the years, always maintaining the goal to improve accuracy as an aid to radiologists. This decision support tool acts like a 'spell checker' that the radiologist can use after the initial case review but prior to their final interpretation. It adds marks to images noting any finding that may seem suspicious. CAD uses pattern recognition algorithms to determine if calcifications or mass-like densities have suspicious imaging characteristics. It is up to the radiologist to decide to agree or ignore these markings. AI based CAD can help with obscure findings that may have otherwise been missed and it can be a helpful decision tool if there is a particular finding that the radiologist is unsure of.

As CAD helps determine what is wrong with an image, it has been met with its share of criticism. Comments have ranged from too many distracting marks on the images, to radiologist disagreements with many markings, to a lack of reimbursement. Over the years, some questioned how much CAD truly helped them. For some, traditional CAD became a bit of a nuisance producing a higher rate of false positive marks. False positive markings increase the risk of unnecessary diagnostic call backs and workups leading to possible biopsies. Historical AI CAD technology is not necessarily a time saver knowing the radiologist needs to study the markings to discern the risk of each. Regardless, many facilities continue to use a form of artificial intelligence via traditional CAD.

Computer aided detection adapted as mammography technology progressed from analog, to digital (2D), and now to digital breast tomosynthesis (DBT, 3D). Traditional CAD works in conjunction with analog and 2D mammography. The principles of AI CAD have changed with DBT and the multitude of images that 3D mammography produces. The uses and benefits of artificial intelligence with DBT mammography has flourished.

With the production of additional images per exam, DBT interpretation time increased to nearly double. The focus of DBT artificial intelligence goals has truly expanded to reduce false positive and false negative rates as well as provide efficiencies while increasing overall detection rate. This is exciting for the future of breast imaging.

Additional Breast imaging

Breast imaging artificial intelligence is used well beyond mammography. Typically, quality breast magnetic resonance imaging (MRI) includes the use of CAD. MRI CAD helps to evaluate suspicious breast lesions for the radiologist. At this time it is unusual not to use CAD with breast MRI.

Progress to reduce interpretation time and add efficiencies continue to expand. AI tools are being developed with breast ultrasound. Reducing interpretation time helps to allow for more time with patients and increase throughput of cases. As contrast enhanced spectral mammography, CESM technology continues to become more widespread, the opportunity to include more AI features emerge.

Impact of Artificial Intelligence

Artificial intelligence is rapidly developing while exploring how it may ultimately improve patient outcomes. MRI, CT, Interventional and diagnostic radiology are just a few additional imaging modalities that AI benefits. With the current pandemic, there are additional opportunities for AI technology to aid with COVID 19 detection and monitoring.

Specific to breast imaging there is promise for AI to provide a reduction of image noise, artifacts, motion and dose. Increased resolution improves overall imaging quality. The synthetic, or computerized images used with DBT makes such image quality improvements a reality.

Mammography AI options now include positioning feedback and review and scoring of breast density which is associated with risk for breast cancer. This density feature removes subjectivity from this score while reducing variability. It can help the radiologist determine the most appropriate density level when challenged with a case that seems borderline, between two levels of density.

With the onset of large data set, deep learning technology, which becomes smarter as it reviews more images, AI can help predict the level of suspicion of a breast nodule. This helps determine which patients may benefit from addition diagnostic work ups. By enhancing relevant regions of interest it also saves interpretation time. Reducing overall interpretation time, whether seconds or minutes per exam, provides more time for patients and increased imaging throughput. Efficiencies enhance report turn-around –time while increasing patient, radiologist, technologist satisfaction. AI tools like this have the potential to help prevent radiologist burnout. Also, with the wide reports of breast imaging backlogs due to the pandemic, AI time saving advances is welcomed technology.

Breast imaging and AI's future

Artificial Intelligence technologies are changing rapidly as the benefits and uses of AI are being realized. I look for further expansion and automation of the use of AI in breast imaging over the next few years. The future will require us to have an open mind and to think 'bigger picture' on how AI can help.

Price points will be key as various breast imaging artificial intelligence products become available. The economic benefits of AI needs to be considered. Cost must be weighed against value, overall savings and reimbursement.

Just as education is important to professionals it is also helpful for the patients. If AI is used for their imaging exam, explaining the role it played in the diagnosis is important. Explaining that AI works to assist the skilled radiologists is being honest and informational.

I feel the most potential for AI technology is with it used as a second, or pre-read, and prioritizing cases. Focus on triaging cases that are in most need of reading first will be very beneficial to patient care and those most at risk of breast cancer. Today, now more than ever, healthcare is faced with workflow challenges and increased volumes making this feature valuable.

Whether Artificial Intelligence is fear provoking or openly embraced, it is here to stay and will only continue to assist the multi-modalities of breast imaging and improve how we care for our patients.

Artificial Intelligence in cardiology

By Christopher Steelman, USA

Christopher Steelman

Christopher is passionate about the role of technology in education. He is a regional coordinator of professional practice for the ISRRT, the chair of the World Radiography Educational Trust Foundation, and chair of the ASRT Foundations International Outreach Review Committee.

He has addressed audiences at the ISRRT 19th and 20th World Congress in Seoul, Korea, and Trinidad & Tobago, the ASRT Educational Symposium, the RAD-AID Conference on Radiology in Developing Countries, and the Association of Educators in Imaging and Radiologic Sciences. He has contributed to numerous publications including Radiology in Global Health and The Heart Revealed, a project of The European Society of Radiology. He is a member of the editorial review board of Cath Lab Digest.

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AI Is revolutionizing the practice of medicine

ARTIFICIAL intelligence (AI) is revolutionizing the way we live, work, and communicate. It autocompletes the sentences as we type, populates internet searches before we complete our thoughts, allows cars to drive themselves, filters unwanted email, and supports language translation. AI is also revolutionizing the practice of medicine. It's assisting doctors to diagnose patients more accurately, make predictions about patients' future health, and recommend more effective treatments. There is an increasing number of exciting applications in the medical imaging field, propelling it forward at a rapid pace. AI can help clinicians diagnose disease and optimize treatment processes, reduce the rate of misdiagnosis, and improve diagnostic efficiency. AI can now recognize medical images and provide clinicians with more reliable imaging diagnostic information. And AI is also accelerating research by giving us the ability to analyze extremely large data sets that were previously difficult to analyze using traditional data processing methods. Artificial intelligence and machine learning (ML) are poised to influence nearly every aspect of medicine, and cardiology is at the forefront of this trend.[2] The unique nature of interventional cardiology makes it an ideal target for the development of AI-based technologies designed to improve real-time clinical decision making, streamline workflow in the catheterization laboratory, and standardize catheter-based procedures through advanced robotics.[3]

The radiographer and cardiac catheterization

The cath lab has come a long way since 1929 when Nobel Prize winner Werner Forssmann performed the first cardiac catheterization on himself. Under local anesthesia, Forssmann inserted a catheter into a vein in his arm. Not knowing if the catheter might pierce a vein, he walked downstairs to the x-ray department where, under the guidance of a fluoroscope, he advanced the catheter 65cm into his into the right atrium.[4] Dr. Forssmann had the radiographer capture an image obtaining documentation of his incredible experiment. The radiographer and cardiology have been inseparable ever since. Today, more than 2 million patients are treated with coronary angioplasty annually.[5] From the beginning, the radiographer has played a fundamental role in the multi-professional teams who treat patients with life and limb-threatening diseases. Contributing far more than an expertise in imaging, today's cath lab radiographer has accepted the challenge of rapidly developing technology and AI will not be the exception.

Global cardiovascular disease

Cardiovascular disease (CVD) is the leading cause of mortality worldwide, accounting for >17.3 million deaths per year in 2013,[6] a number that is expected to grow to >23.6 million by 2030.[7]

Deaths attributable to ischemic heart disease increased by an estimated 41.7% from 1990 to 2013.[8] Coronary heart disease (CHD) is the single largest cause of death in the developed countries and is one of the leading causes of disease burden in developing countries. In 2001, there were 7.3 million deaths due to CHD worldwide.[9] An ST-segment elevation myocardial infarction (STEMI) is a serious form of a heart attack in which a coronary artery is completely blocked and a large part of myocardium is unable to receive blood. "ST-segment elevation" refers to a pattern that appears on an electrocardiogram (EKG). This type of heart attack requires immediate, emergency revascularization which restores blood flow through the artery.

Time is muscle

Patient delay is a worldwide unsolved problem in STEMI. STEMI interventions are unique in that the entire process is enormously time-dependent and the outcomes are linearly correlated with the system efficiency. Rapid diagnosis is critical in STEMI to facilitate timely intervention and requires immediate ECG evaluation. The 2013 ACCF/AHA and the 2012 and 2017 ESC guidelines stress the importance of obtaining a 12-lead electrocardiogram (ECG) in a timely fashion (≤10 mins of presentation).[10,11,12] Door-to-balloon (D2B) is a time measurement in emergency cardiac care specifically in the treatment of STEMI. In patients with ST-segment–elevation myocardial infarction, timely reperfusion therapy with D2B time <90 minutes is recommended by the current guidelines.[13] The interval starts with the patient's arrival in the emergency department and ends when a catheter guidewire crosses the culprit lesion in the cardiac cath lab. Every minute of delay in treatment impacts mortality. The mortality of patients increases by 7.5% for every 30 minutes that elapse before a patient with ST-segment elevation is recognized and treated.[14] It has been reported that a change in D2B from 15 to 180 min would lead to an increase in in-hospital mortality of 3% to 8.5% and an increase in 6-month mortality from 10% to 20%.[11]

AI and the diagnosis of acute myocardial infarction

Prehospital diagnosis of STEMI is of major importance in reducing time to treatment, in particular when patients can be transported directly to a facility with a cardiac catheterization lab, also known as a "cardiac cath lab." However, obtaining 12-lead electrocardiography (ECG) for STEMI is cumbersome, and inefficient, relying on experts for confirmation. Considering the critical role ECG plays in the early detection of STEMI, an accurate warning system based on electrocardiogram (ECG) may be a solution for this problem, and AI may soon offer a path to improve its accuracy and cost-efficiency. An ECG monitor equipped with a specific algorithm to automatically detect ST-segment elevation could theoretically help in pre-alerting STEMI and reducing patient delay. A potential application of this AI-based ECG algorithm is its use by paramedics in ambulance and physicians from the referred hospital and clinics. It was reported that the inappropriate activation of a cath lab for STEMI was around 20–25%[15], which was a great waste of medical resources. The application of this AI-based algorithm has the potential to empower a broader range of physicians to more accurately diagnose STEMI on ECG and reduce the inappropriate activation of the cath lab. This AI-based STEMI algorithm may contribute greatly to the improvement of the current STEMI system around the world. AI application in ECG evaluation leads to higher accuracy and specificity, along with a faster diagnosis. Faster diagnosis, in particular, translates into improved triage of patients by decreasing unnecessary transfers while improving outcomes and therefore, reducing costs.[16]

AI and the treatment of acute myocardial infarction

The cardiac intervention has been the main treatment for cardiovascular disease in recent decades, including CHD and acute coronary syndrome.[17] Interventional cardiology has traditionally been at the leading edge of cardiovascular innovation. The past decade has seen an increasing emphasis on invasive intravascular imaging and physiology, exercise hemodynamics, robotics, and a progressive blending of minimally invasive (as well as invasive) cardiovascular surgical procedures.[18] Soon, by using deep learning, AI will have the ability to identify coronary atherosclerotic plaques more accurately than clinicians. Early research into the application of AI to assess coronary arteries has included a recent study that validated the noninferiority of AI to determine the physiologic importance of coronary lesions and recommendation for revascularization.[19] In addition, AI can also be used to analyze echocardiographic images, including automatic measurement of the size of each chamber and assessment of left ventricular function. Moreover, it can be used to assess structural diseases, such as valvular disease, to help determine the classification and staging of the disease.[17] AI can be incorporated into the various specific components of both the STEMI process and the procedure. It can foster large efficiency gains by simplifying each of the various components, be that at the individual patient, paramedic, ED, or the cath lab. Predictive diagnostics, therapeutic strategy design, device selection, procedural optimization, and avoidance of complications are all areas in which the application of AI is expected to make a rapid progression.

AI at home

Patient data will not be collected solely within the health care setting. Out-of-hospital cardiac arrest is a leading cause of death worldwide.[20] Rapid diagnosis and initiation of cardiopulmonary resuscitation (CPR) is the cornerstone of therapy for victims of cardiac arrest. Yet a significant number of cardiac arrest victims have no chance of survival because they experience an unwitnessed event, often in the privacy of their own homes. The proliferation of mobile sensors will allow physicians of the future to monitor, interpret, and respond to additional streams of biomedical data collected remotely and automatically.[21] Recent technology has provided access to a reliable means of obtaining an ECG reading through a smartphone application.[22] This technology could conceivably be widely disseminated and paired with ML interpretation to rapidly triage patients with STEMI. Expedited transfer to a facility capable of percutaneous coronary intervention could then be facilitated in a timelier manner, potentially improving outcomes. An under-appreciated diagnostic element of cardiac arrest is the presence of agonal breathing, an audible biomarker, and brainstem reflex that arises in the setting of severe hypoxia. ML algorithms have been employed to analyze home recordings via smart home speakers and phones to identify agonal breathing.[23] Accurate detection of such recordings could allow for the detection of arrest and activation of emergency response in the large percentage of arrests that occur unwitnessed at home.

The use of AI to assess cardiovascular variables has gone mainstream as is now being incorporated into wearable devices. The most prominent example is the Apple Watch, backed by the American Heart Association and U.S. Food and Drug Administration clearance. This wearable device can detect atrial fibrillation.[21] Via photoplethysmography, the device traces changes in blood flow and pulse. This information is translated into a tachogram that is processed via an AI-powered algorithm. If an irregular pulse is detected, the algorithm can detect atrial fibrillation with a positive predictive value of 84%. The user is notified to seek medical attention via an application installed on their iPhone. This is a clear example of how technology can bring us closer to the patient and improve screening, diagnosis, and at-home patient monitoring.[24]

Applications in Low and Middle-Income Countries

Three-fourths of global deaths due to CHD occurred in the low and middle-income countries.[25]

In developing countries, rapid economic transformation leads to environmental changes and unhealthy lifestyles; in addition, population aging may increase cardiovascular risk factors and increase the incidence of CVD.[26] CVD has placed a heavy burden on patients and society as a whole. Therefore, it is necessary to provide strategies for improving the diagnosis and treatment of CVD in the future. AI may have the potential to solve this problem.

Medical AI technology not only could improve physicians' efficiency and quality of medical services, but other health workers could also be trained to use this technique to compensate for the lack of physicians, thereby improving the availability of healthcare access and medical service quality. Recently, healthcare in China's rural areas has been benefiting from medical AI technology. According to a news report from the *South China Morning Post*, a portable all-in-one diagnostic station (weighing 11 pounds), which can run 11 tests, including blood pressure, electrocardiographs, and routine urine and blood analyses, has been used in village healthcare settings. This device, which was developed by an internet healthcare company supported by a national rural healthcare program, can automatically upload results and medical records to an online data analysis system and generate a diagnosis for village health workers to review and reference.[27]

The role of the radiographer

The cath lab-based radiographer has been keeping pace with the rapidly evolving field of cardiology since first catheterization 1929. There have been major advancements in the use of AI in recent years in nearly all areas of cardiology, with some concrete advances in ECG analysis, automatic interpretation of imaging studies, and risk prediction. However, AI is susceptible to major errors in interpretation, validity, and generalizability, raising safety, and ethical concerns. The opportunity for dose reduction and image optimization using algorithms are some elements of a radiographer's current role that could be augmented with AI, but radiographers will still be responsible for keeping radiation doses as low as reasonably achievable. Adoption of AI in medical imaging requires radiographers to adapt their imaging practices to ensure new technology is being implemented, used, and regulated appropriately, based on high-quality research evidence, maximizing benefits to their patients.[28] The successful application of AI will require close collaboration among computer scientists, clinical investigators, cardiologists, radiographers to identify the most relevant problems to be solved and the best approach and data sources to do it.

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USA

American Society of Radiologic Technologists

ASRT 2019 Artificial Intelligence survey results

THE American Society of Radiologic Technologists has over 157,000 members and is committed to advancing and elevating the medical imaging and radiation therapy professions to enhance the quality and safety of patient care. We do this by staying abreast of current and future technological changes and seeking to understand professional acceptance of coming changes. To better understand the advancement of Artificial Intelligence in Medical Imaging and Radiation Therapy, the ASRT conducted a survey of its members. The 2019 Artificial Intelligence Survey was sent via email to 20,000 ASRT members in August 2019. A total of 416 participants completed the questionnaire, for a 2.1% response rate. This sample size yielded a margin of error of ± 4.8% at the 95% confidence level. Most participants work at a hospital (58.6%), while many others work at an imaging center (10.2%) or a large clinic (8.5%) with the majority in an urban setting (44.9%) or suburban setting (38.8%). The remaining 16% work in a rural setting. The respondents are staff technologists or therapists (69.2%), chief technologists (9.7%), and supervisors or assistant chief technologists (5.8%). Most work full time (82.3%) and the average age of respondents is 42.9 years.

Artificial Intelligence (AI) is broadly defined as the simulation of human-like intelligence by machines. The challenge of AI is designing computer systems to perform tasks that require human intelligence, including visual perception, speech recognition, and decision-making. Machine Learning (ML) is one approach to artificial intelligence that gives computers the ability to learn without being programmed. Most respondents agreed that these definitions matched their understanding of these concepts (88.6% AI and 72.4% ML).

Survey results suggest that respondents, who primarily work in radiography (54.7%), computed tomography (20.7%), and mammography (13.3%), are largely comfortable with technology and frequently use it in their everyday life. Though most respondents are broadly familiar with the concepts of AI and ML, they have mixed experiences with AI features on imaging equipment. Regardless, many are confident that those features function correctly and provide trustworthy results. One area of concern was the lack of standardized processes for resolving discrepancies between machine-recommended procedures and technologist judgment. However, the majority feel that AI will have a positive impact on safety and quality, with a mild concern that "human" aspects of the profession such as patient interaction and creativity could suffer. There was no consensus that AI would adversely affect their professional prospects.

AI and ML features of equipment were analyzed for several modalities, and results were cross tabulated to factor out equipment that technologists do not regularly operate. Self-driving, guidance, and automatic positioning were the most recognized AI and ML features across modalities, except for radiation therapy. Anatomical detection also was quite common. Some examples of anatomical detection include vessel detection in vascular intervention, structure contouring for radiation therapy, and automatic image reconstruction for magnetic resonance imaging. Nearly 55% of respondents noted that automated postprocessing is common practice in their department. Respondents were asked how frequently they use AI and ML features of equipment, and over 18% stated they "use them all the time", 34.5% "use them most of the time", 20.9% "use them some of the time", 10.4% "rarely use them", and 15.9% "never use them".

The areas respondents feel AI and ML will most benefit practice are motion artifact recognition (72.2%), radiation exposure control (71.4%), and quality of scans and treatments (70.4%). Respondents foresee a neutral effect on throughput (53.2%), creativity (52.9%), and responsible implementation (52.4%), as well as negative effects on patient interaction (30.8%) and expense (25.6%). A majority (53.5%) believes AI will not affect the technologist's scope of practice. Nearly 31% of those age 18 to 24, the largest age cohort, believe their role will be expanded, 33% of respondents age 34 to 43 believe AI will reduce their professional role, and 80% age 63 or older anticipate no change, likely due to retirement. Lastly, the survey evaluated how technologists perceive AI and ML will affect staffing and specialized roles. Almost 63% of respondents across all age groups believe staffing will not be affected. Those age 34 to 43 are most concerned about a staffing reduction, and respondents 63 and older are the least concerned. The 54 to 62 age group somewhat believes additional staffing will be necessary. Half of the 18 to 24 group believes AI will lead to the development of new roles within the profession, while the 25 to 33 demographic is most likely to anticipate a reduced role.

Technologists are mostly comfortable with technology in everyday life, use it daily at work and are cautiously optimistic about the incorporation of AI and ML technologies in their departments. Most respondents somewhat trust AI algorithms or trust them a great deal. The results are encouraging and demonstrate current use of AI and a general acceptance of change. The majority feel that AI will have a positive impact on safety and quality, with a mild concern that "human" aspects of the profession such as patient interaction and creativity could suffer. While it is generally believed that AI could elevate patient care, we must assure that the human aspect of imaging remains.

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Cambodia

AI In Cambodia

Elevating Patient Care with Artificial Intelligence
"Radiographers are essential in elevating patient care with artificial Intelligence"

Objective

As a post-conflict nation, emerging from decades of civil war, Cambodia faces limitations on its country-wide infrastructure, but gaps in nascent systems can present a unique opportunity to innovate with digital technologies such as AI (artificial Intelligence). It was assumed that economic development required industrial infrastructure. But the fourth Industrial revolution offers the possibility for any country to simply leapfrog infrastructure development. As Cambodia is a developing country, so the Artificial intelligence in medical and healthcare has been a particularly under considering for hospital and organization, I have seen a small number of AI. Venture companies attend in Cambodia, its upcoming wave of trends is coming a few years before which affected with the price. For our experience what AI can perform in Cambodia is gathering of data through patient interviews and tests processing and analyzing results using multiple sources of data to come to an accurate diagnosis determining an appropriate treatment method often presenting options preparing and administering the chosen treatment method patient monitoring, an additional AI methods excel at automatically recognizing complex patterns in imaging data and providing quantitative, rather than qualitative, assessments of radiographic characteristics and a lot of advantages to use A in work place. However, if we could has are many applications of AI within radiology that are beyond image interpretation and may even be implemented much earlier in actual practice enhance radiology through improving imaging appropriateness and utilization, patient scheduling, exam protocoling, image quality, scanner efficiency, radiation exposure, radiologist workflow and reporting, patient follow-up and safety, billing, research and education, and more to improve, ultimately, patient care, helpful for doctor finding the cause of disease and provide specific treatment to patients, help decreasing patient visited abroad to get medical service from there.

Methods

Presently collaborations between hospitals and industry, Cambodia has a several abroad company were investments in medical field that used AI for provides service to local patients and traveling patients such as treatments and diagnostic criteria by offering international standard medical services in the capital, and our expected is look into how much AI can be attend in Cambodia in the future even currently AI system was used in several hospital and only private hospital or diagnosis center, because the AI price were a problems even this technology is used in health care is very helpful for doctors recognize diagnoses and tell when patients are deteriorating It can save costs for both the hospitals and patients and precision of machine leaning can detect diseases such as cancer disease sooner and can get the right way treatments and saving patients life, best medical service, accurate diagnosis and trust patients information before the patient needs hospitalization, however AI could be takes data from patients to help improve patient outcomes, It improves reliability, predictability, and consistency with quality and patient safety and will increase efficiency, it improves human performance, it is used as a decision augmentation tool, while it can't replace doctor and nurses, it can make them more effective, efficient and happier on the job which increases confidence as well as reduces stress and anxiety.

Conclusion

In the future we looking for deployment of AI represents a unique challenge for every nation and nowhere more so than in the improvement of healthcare. Cambodia faces unique challenges and opportunities anchored in its unique social and technological infrastructure and will serve as a model for technology deployment in tackling common global problems develop a medical education system to create a workforce competent in the utilization, evaluation, and improvement of AI and to deploy thoughtful multidisciplinary and multilateral efforts to identify and disseminate best practices from patient-care to system-wide management. Through such an approach, it is uniquely situated to demonstrate to the world a well-designed roadmap of an AI-driven future of healthcare.

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Artificial Intelligence in diagnostic radiography

FROM the invention of the earliest diagnostic imaging devices using Roentgen inspired X-ray tubes in the early 1900s to the use of non-ionising radiation technologies of today such as ultrasound and magnetic resonance imaging[1] the profession of the radiographer has required constant adaptation in the face of rapid technological developments. Not only adaptation to technology were required but constant role expansion including the management of risks of using imaging technologies that were missed by the early pioneers.

Radiographers have been using "machine intelligence" for quite some time in the form of Automatic Positioning of equipment based on procedure in interventional radiology suites, Automatic Exposure Control (AEC) of X-ray imaging systems and segmentation tools or computer aided detection in image post-processing to name but a few. The level of automation continues to grow year on year with additional tools being provided to assist the radiographer/RT in the performance of their duties. It is therefore of no surprise that we will see the evolution of these assistance tools with the growth of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) technologies. Many papers consider "Is AI a threat to our profession"[2] and we need to be aware of the implications for the radiography profession.

Key to this is understanding what AI/ML/DL can and cannot do. It is, when well developed, an incredible system for rapidly determining patterns or sequences that can be difficult for humans to understand in a timely fashion. It can assist with many arduous duties like radiation dose control but do not let the word intelligence in AI fool you into thinking it is all knowing. Even with AEC we still have seen over exposure instances that "machine intelligence" did not prevent Richwine[3].

Machine learning loves data that contains repeatable, even if difficult to identify, patterns which occur in a lot of real-world digital data. But what about emotional data, mis-understanding the meaning of a simple smile can have serious consequences for action[2]. AI efforts are being made to recognise meaning in speech, as opposed to word/phrase recognition but they are not exhibiting true understanding of speech and this can result in problems[4]. AI suffers from bias[5], lacking the potential to adapt given the constraints of its localised area of operation (or domain) and the data available to it (6). Human communication is complicated and patients require more than "the illusion of intelligence or humanness"[4].

AI is part of radiography, quite literally. Recognising the strengths of the human factor in the role and effectiveness of the profession means we need to keep the human in any development in AI. We need to set aside dividing lines and think of it not as Artificial Intelligence but rather Augmented Intelligence[7], with us as part of the equation (or algorithm even) and this is the next adaptation of the profession. We should welcome improved decision support tools that enhance our performance and the care of our patients and we should also to continue to monitor the examinations to ensure sacrosanct principles such as ALARA are maintained. We can use the improved patient contact time afforded us by this technology (just as we did with the replacement of film-screen by digital images) to focus more on our patients making sure they are better informed, better prepared and ultimately provided better healthcare.

In this respect, radiographers have not only an ongoing role in adopting this AI technology, but also in being part of the development, testing, and safe, supervised use of this technology.[8]

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Artificial Intelligence in radiation therapy

Radiation Therapists (RTTs) have a well-recognised thirst for progress, and a willingness to embrace advances in technology. With these inherent professional qualities, it comes as no surprise that the integration of artificial intelligence (AI) into clinical practice has been explored across a number of areas of radiation oncology. This brief overview will highlight the some of the current uses of AI throughout the chain of radiation therapy and will demonstrate the potential impact on clinical practice.

We have seen from our professional counterparts in diagnostic radiography, that there are many benefits of AI related to image acquisition. With this application extended to radiation therapy, AI methods have enabled the generation of synthetic CT images based on MRI data. Through the use of complex neural networks (CNN), the high-resolution synthetic CT images generated are of sufficient quality for radiotherapy planning purposes[9]. This application is promising as it negates the need for a potentially unnecessary planning CT to be acquired, paving the way for MRI only simulation, thereby reducing dose to the patient and improving workflow. Furthermore, as Rattan et al., point out, the combination of MRI and CNN generated synthetic CTs reduces image fusion uncertainties which could potentially impact on delineation and treatment planning downstream[9].

Image segmentation is arguably one of the most time-consuming aspects of radiation therapy and here we are reaping the benefits of AI that has pushed us beyond the current standard practice of atlas-based auto-segmentation. Multiple studies in the literature have demonstrated the significant reduction in contouring time, for example Lustberg et al., reported a median time saving of nearly 80% through the use of deep learning methods.[10] With the shift towards online adaptive radiotherapy (ART) where delineation, optimisation and dose calculation occur whilst the patient is on the treatment couch, this resultant reduction in burdensome contouring tasks is particularly valuable. Spieler et al., illustrated this particular application with their recent online ART study for patients with pancreatic cancer; a site which is particularly challenging to contour.[11] While most of the studies in AI driven segmentation acknowledge a consistent reduction in time, there have been mixed results reported with respect to contouring accuracy. And whilst more work is yet to be done in this field, sub-optimal preliminary results are predominantly caused by inconsistencies in the manual contours found within the model training datasets.[10]

Knowledge-based planning is not a new concept in radiotherapy and has resulted in improved efficiency in plan generation, as well as improved consistency in the quality of plans between individual planners. The integration of AI in this regard was the next natural step and has also garnered interest in the literature. One such example of this novel application was demonstrated by Fan et al.[12] Here, using deep learning algorithms, a model was trained based on 270 nasopharyngeal IMRT plans to predict the dose distribution of subsequent patients. Following validation, their model was able to not just predict an achievable distribution, but also converted this information into usable optimisation parameters to automatically generate a clinically acceptable plan. By selecting a disease site that is notoriously time consuming to plan, Fan et al., have clearly demonstrating the promising scope for AI in treatment planning.[12] Furthermore, head and neck patients often require unscheduled ART due to weight loss and tumour shrinkage during treatment. The role of AI to expedite the laborious planning process prevents potential breaks in treatment, which from a radiobiological perspective is particularly attractive for this specific patient group.

Transferring AI methodologies from a confined research setting into the clinical environment will have a tangible impact on department workflow and patient care. The scope to reduce any existing disparities in quality of care by exploiting AI to allow for knowledge transfer between staff and across institutions is particularly exciting.[13] Likewise, is the scope for RTTs to advance their practice even further and adapt our professional roles in ways we never imagined.

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Japan

Usefulness of AI (Artificial intelligence) in Japan

AI (Artificial intelligence) is now being used in various situations in Japan. In the medical field, it has been picked up as the latest topic such as doctor's support diagnosis assistance[1,2] and patient assistance in rehabilitation. Regarding the support diagnosis of doctors, it is a so-called CAD (computer-aided diagnosis), which started in 1960 and has a history of over 20 years. This CAD is now called AI-CAD, which uses AI for machine learning and deep learning. The accuracy is improved, and further evolution is expected in the future. In the field of radiological diagnosis, it has begun to be adopted in most fields such as general imaging, CT (computed tomography)[3], MRI (magnetic resonance imaging)[4], nuclear medicine[5], radiotherapy.[6] In particular, it has become possible to reduce the radiation dose to patients by using AI to obtain conventional image quality with a low-dose X-ray. It has been able to perform with high accuracy examination than so far by incorporating AI into software. In the CT field, if AI is introduced into the dual energy technology and accuracy is improved, it is expected that the examination will be able to obtain more information such as functions from the examination that was mainly based on morphological information. There are machine learning, neural network, and deep learning in AI. Neural networks are a method of machine learning that mimics the neural network of the human brain. Deep learning is being learned and advanced by itself. Although these are collectively called AI, they are applied to the medical field by taking advantage of their respective characteristics.

I am going to introduce some parts of CT in my specialty. In my current research, AI is not used for reconstruction, but it is used in the calculation process to speed up calculation. The images of the coronal section of the chest phantom with simulated nodule taken with conventional dose (SD(standard deviation) 10, CTDIvol(volume CT dose index): 12.7mGy, DLP(dose length product): 402.9mGy-cm, Effective dose: 5.64mSv) and low dose (SD17, CTDIvol: 4.4mGy, DLP: 139.3mGy-cm, Effective dose: 1.95mSv) are shown below. The effective dose was calculated using adult chest k-factor (0.014 mSv-mGy-1-cm-1) of ICRP Pub.102. In the past, when trying to reconstruct a low-dose image to ensure the conventional image quality, it took a long time to calculate and was difficult to use clinically. Although, it is possible to speed up the process by using machine learning in the calculation process and make it easier to use clinically, and it is possible to reduce radiation dose by about 35% without degrading the image quality (under figure). However, the image reconstruction and software using these AIs are black boxes, and there are few detailed explanations from manufacturers. Therefore, "Is the image and data output after scanning really correct?" "Can the radiation dose be reduced?" It is a problem point of AI that it is not known at present how to output images and data and it is a future task to clarify it. It is considered necessary to evaluate the accuracy of the data and the information output by AI. In the future, it is thought that our radiological technologist, will be able to provide a better examination with minimally invasiveness for patients by elucidating and using it.

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Elevating patient care with Artificial Intelligence: Radiographers are essential in elevating patient care with Artificial Intelligence: Perspectives of Nigerian radiographers

Introduction

RADIOGRAPHERS worldwide have been at the fore front of the use of modern digital technology in medical imaging and radiation therapy for improved patient care. This is because they have maintained the human touch between emerging technologies and the patient over the years. It is against this background that the Association of Radiographers of Nigeria (ARN) throws its weight behind the position of the International Society of Radiographers and Radiologic Technologists (ISRRT) which is the voice of Radiographers worldwide that; Radiographers are Essential in Elevating Patient Care with Artificial Intelligence.

While the development and deployment of Artificial Intelligence in health care in most low and middle income countries, Nigeria inclusive is yet to fully take root, as proactive professionals, we recognize the fact that the future is now. Hence an urgent need for adequate preparation. We therefore urge the ISRRT.

Our Position

It is important for us as radiographers to ask ourselves this important question, whether our data landscape is ready to accommodate artificial intelligence. This is important because radiographers generate enormous amount of data in the course of imaging patients during medical imaging and radiation therapy procedures every day. The modern health care ecosystem which also includes radiography is ever dynamic, complex and data driven. Data is considered the most valuable asset of the 21st century. Data if used in Artificial Intelligence (AI) workflow can transform device, give back the gift of time to clinicians and maximize patient care especially in disease recognition and interpretation.

A new model that was developed, called the LOAD model that can assist in identifying factors that can cause problems when we introduce new functionality like machine learning (ML) workflows to complex ecosystems. The LOAD model stands for; Landscape; Organization; Action; Data. The model describes four dimensions that can affect the adoption of new digitalization innovations such as AI tools. The rationale of the model is to provide some structure on identifying socio-technological factors when implementing new AI tools to be embedded in complex environments. Some of this tools includes image segmentation and image interpretation in radiotherapy. By interrogating the four dimensions of the LOAD model, domain experts are covering factors, stemming not only from technical, but also from organizational and human sources. In the LOAD model, the data remains the focal point of investigation. All the other dimensions are analyzed from the data perspective.

The LOAD model was a concept developed based on research on factors contributing towards the failure to realize the planned benefits of new technologies, IT systems in the NHS in the UK. The study analyzed 18 case studies by staff working for the NHS. The case studies describe factors responsible for failure or success of recent developments due to a mixture technical and human factor with human factors being by far the most dominant. The most common cause of IT failure in these case studies is related to people and their interactions.

Hence, to investigate if our current data landscape is ready for new machine learning techniques and tools, we have to investigate not only the technical but also the human and organizational factors that can pose any threat to the new project.

The data dimension of the model describes factors introduced by the data needed to be used in the new system or functionality. Data entry is a time consuming process and when done by a less experienced staff could introduces error which could significantly reduce the quality of information.

People and systems interacting with data to accomplish some value are referred to as actors. For example data entered into a system by secretarial staff can contain error if the information requires medical knowledge vocabulary that the staff lacks. We refer to this as the risk of a class of grammers.

Moving onto the organization dimension, sharing outside immediate organizational unit can result in a number of administrative costs, such as reaching and complying with data sharing agreements, as well as complying with wider information governance requirements. The data landscape finally describes the environment in which the other three components; organization, actors and data interact.

Preparing the radiography workforce that will deliver the digital future by elevating patient care with artificial intelligence entails a critical review of important aspects and future practice as radiographers; how technological and other developments is likely to change the roles of radiographers over the next two decades to ensure safer, more productive, more personal care for patients; the implications of these changes are for the skills required by radiographers filling these roles; the consequences for selection, curricula, education training, development and lifelong learning of qualified radiographers and those in training are key competences that AI intends to address in our national policy.

AI has been identified as one of the means of addressing the health care challenges of the 21st century. There must be mechanisms in place to ensure advanced technologies do not dehumanize care. While automation will improve efficiency, it should not replace human interaction.

Important points to support deployment of AI in Radiography and Radiation Therapy Practice:

1. The emergence of artificial intelligence(AI) as a tool for better health care offers uncommon opportunities to improve patient and clinical team outcomes, reduce costs, and impact population health. Examples include but are not limited to automation; providing patient, family (friends and family unpaid care givers), health care professionals information synthesis, recommendations and visualization of information for shared decision making.

   Nigerian radiographers while being cognizant of the numerous promising examples of AI applications in health care as seen in literature both within and beyond radiography believe that it is important to proceed with caution, else we may end up with user disillusionment and another AI winter, and/or further exacerbate existing health and technology driven disparities. Radiographers are relevant stakeholders in elevating patient care with artificial intelligence in health care.

2. Considering the fact that AI tools are being implemented in an environment of low regulation and legislation particularly in low resource settings, it is important to ensure that human-centered AI tools include accepting that human override is important for developing user-trust because the public has an understandably low tolerance for machine error.

3. The near term dialogue around AI in health care should focus on promoting, developing, and evaluating tools that support humans rather than replace it with full automation systems reliance on data.

   AI Data are critical for developing any AI algorithm. Without data, the underlying characteristics of the process and outcomes are unknown. Paucity of quality data in health care has been a challenge in health care for decades, but key trends (such as commodity wearable technologies) in this domain in the last decade have transformed health care into a heterogeneous data-rich environment (Schulte and Fry, 2019).

Databias

Selecting an appropriate AI training data source is critical because training data influences the output observations, interpretations, and recommendations. If the training data are systematically biased due, for example, underrepresentation of individuals of a particular gender, race, age or sexual orientation, those biases will be modeled, propagated, and scaled in the resulting algorithm. The same is true for human biases (intentional or not operating in the environment, workflow, and outcomes from which the data were collected.

Recommendations

- Radiographers as well as clinicians must consider the potential impact of the patient to radiographer relationship in the age of AI-enabled health care.
- To achieve high performance ,radiographers should carefully consider strategies for advancing compassionate, high quality care within the digital ecosystem .

To participate in the shaping of AI practices and AI organizations, professionals must have the competencies and the capabilities to participate in the development and shaping of the future of their discipline and practice.

- For Radiographers and other health professionals to stay relevant, they must ensure that their trainees have the required competencies and that their active

- members evolve their capabilities to adapt their practices in an AI-enabled environment.
- How vast are radiographers to harness the knowledge, skills, and attitudes to effective usage of AI tools to improve outcomes for patients and their communities

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South Africa

Society of Radiographers of South Africa: 1st Virtual Symposium - 'Radiographers are essential in elevating patient care with artificial intelligence'

ARTIFICIAL intelligence (AI) has been predicted as taking over radiology. These predictions may be 'attention grabbing' however it is highly unlikely that a machine will replace us anytime soon. AI will augment but not replace and take over the profession.

The Society of Radiographers of South Africa (SORSA) identified the important role of AI in our profession. We are proud to announce that we hosted our first virtual symposium on September 12, 2020. The theme of the symposium was aligned with the ISRRT World Radiography 2020 theme: Radiographers are essential in elevating patient care with artificial intelligence. The symposium was complimentary to all delegates nationally and internationally, but registration was necessary. It was accredited for 2 ethics and 1 general CEU (continuing education unit) and delegates had to indicate if they required CPD certificate. Attendance was monitored per session. Registrants may access the pre-recorded presentations via the zoom platform. The presentations are available for 90 days after the symposium.

The speakers were of exceptionally high calibre, each one being an expert in his/her respective field. They covered subjects related to the ethics and the medico-legal aspects of AI. Presentations pertaining to the education required for AI, and programmes related to scheduling in AI for the ease of the radiographer were also covered.

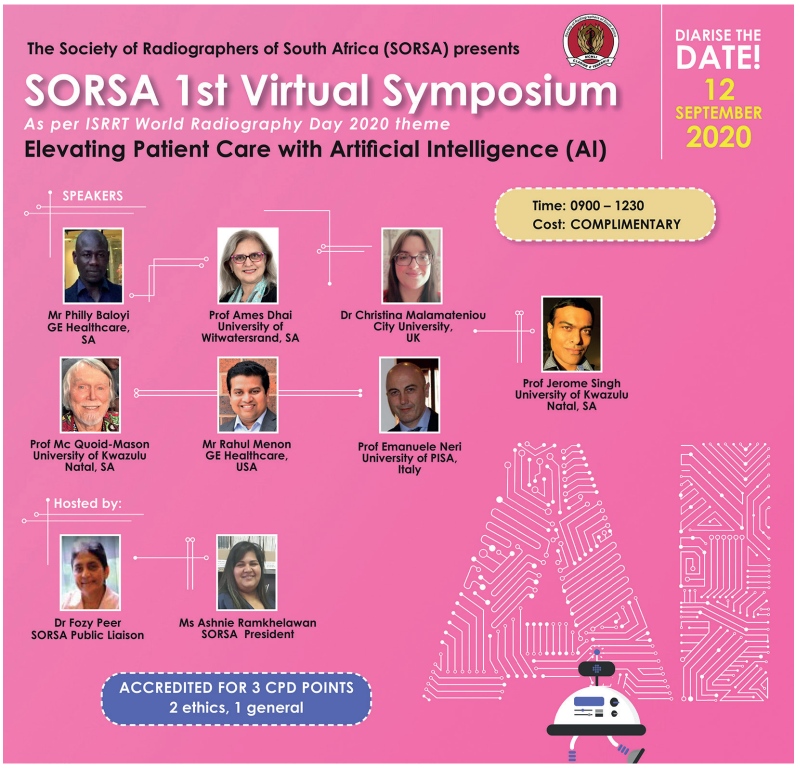
There were just under 500 registered delegates. The delegates interacted with the speakers throughout the presentations and results from the polls and surveys indicate that delegates not only found the symposium to be of value but suggest that more needs to be covered related to AI and the radiographer. Well done to the ISRRT for choosing this theme for WRD 2020.

We are fortunate and grateful to our sponsors who assisted in making this symposium a success.

Please check www.sorsavirtual.co.za for more information.

Watch this space for an upcoming symposia - www.sorsavirtual.co.za and the Society of Radiographers of SA_NC facebook page.

Fozy Peer
SORSA: Public Liaison Officer



Singapore

Elevating patient care with Artificial Intelligence: Radiographers are essential in elevating patient care with Artificial Intelligence

ARTIFICIAL Intelligence (AI) has made significant advances in radiological and radiation oncology. AI is already a synonym in radiology for image interpretation and decision-making, allowing it to complement the clinical practice for safe, quality care. Progress in machine learning, deep learning, neural networks, natural language processing, and quality datasets, will undoubtedly catapult the possibility to utilise AI to enhance the capacity for patient care. We discuss the other areas where this technology can show great potential in the patient care continuum and its implication to our practice.

AI utility as an optimisation tool has already gained traction in imaging. In computed tomography (CT), deep learning image reconstruction (DLIR) and AI algorithms allow the use of low radiation dose without compromising final image quality. Newer CT models now carry a myriad of AI-based features designed to simplify and automate the CT workflows. An example is auto-positioning of the patient to the isocentre of the bore for different CT exams, reducing the risk of incorrect positioning and reduces the number of steps needed for patient positioning. Similar opportunities for image optimisation and shorten scan time exists in MRI, which may be augmented with AI. The ability of AI to improve precision leads to better turnaround time and patient outcome.

The use of AI-powered chatbots is benefits both patients and providers. Chatbots provides the ability to connect with patients and is commonly used to understand patient queries related to their appointment, schedule appointment, sending reminders to patients and triaging a patient's condition based on their inputs. This ability automates roles traditionally manned by customer support. AI chatbots can also be extended to clinical staffs. For instance, during the COVID-19 pandemic, AI chatbots were introduced to National University Hospital (NUH) clinical staffs to retrieve vital information rapidly, such as COVID-19 protocols and hospital guidelines. High availability of complex data for clinical and non-clinical decision-making maximises the role of clinical staffs in improving patient pathways.

We have seen an explosion of AI tools being developed and validated to aid radiologists in confirming COVID-19 infections. Another emerging AI trend is on radiotherapy treatment planning which promises a more automated segmentation of tumours and sensitive organs. Existing methods for the same task takes days for a planner to design for each patient. AI technology will continue to evolve and be a disruptive force in medicine. The radiography profession must appreciate the true disruptive potential of AI and exploit the benefits that this technology brings.

The challenge for the profession is to remain adaptable to technological innovation. To do so necessitates that the medical radiation professions of both diagnostic and radiation therapy tracks be engaged and shape the conversation on AI to inform our future practice. One way is through aligning our expectation of AI by understanding what AI can and cannot do, and how, by harnessing AI, can we deliver excellent patient care.

Members of this profession must play an active role in the development, implementation, safe use and validation of AI applications in medical imaging and radiation therapy. Radiographers need to be adequately equipped with the right skills to leverage these new technology-driven solutions. Doing so allows practitioners to be informed of up-to-date practices to their imaging and treatment practices and prepare for the change needed to adapt to the new technology. As gatekeepers in medical imaging, radiographers must understand the fallability of AI technology, and that behind all that technology is a competent radiographer utilising it to deliver safe care which benefits the patients.

Digital competence of radiographers can be mapped as part of undergraduate education with elements of genomics, data analytics and AI embedded in the undergraduate curriculum. In this way, we can be confident that radiographers will have the foundation and appreciation for such technological advancements.

While AI can take over mundane tasks and free up radiographers, it can never replace the human touch. It will be a matter of time until AI will be the new operative, the new norm, in the delivery of care in the imaging department. Knowing how to interact, adapt and utilise such technology will ensure the sustainability of the profession.

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Trinidad & Tobago

Impact of AI on patient care in CT:
Article is a "Collaborative piece" from The Society of Radiographers of Trinidad and Tobago

SINCE Computed Tomography (CT) was introduced in 1973, the one constant in the industry has been that of change. CT evolution includes changes in CT generation, beam geometry, beam width, detector width, number of slices, detector technology, tube technology, rotation times and changes to image reconstruction methods. Patients have been the main beneficiaries of these changes as the developments have been primarily aimed at shortening examination time, lowering radiation dose, reducing contrast media, improving pathology detection and improving overall image quality and exam efficiency. These developments have mainly been hardware related and the limits of hardware enhancements have been pursued and pushed for almost 50 years. In today's environment we see the impetus for further improvements being increasingly driven by software technology, enabled by advances in computer processing power. Artificial Intelligence (AI) in particular, is the latest software vehicle set to further revolutionize the delivery of CT, further streamlining efficiency, safety and effectiveness. While CT technology has continued to evolve, so too has the notion of patient care. The expressions and definitions of "patient centered care", "patient experience" and "patient engagement"[1,7] have emerged through the years as a testament to how quality of care received by our patients is defined. Consequently, a review of the impact of AI on patient care in CT should also mirror this scope.

Before we delve into understanding AI and explore the aspects of AI in CT that impact on patient care, consideration should be given to some patient care concerns in CT. The scanner with which we work, becomes in many instances, an extension of ourselves; however, what is second nature to us can be very intimidating to the patients we serve. As radiographers, we find ourselves having to act as a bridge between our patients and this technology. Apart from technology, patient throughput, time constraints and complexity of tasks often put us at odds with patient centered care and patient engagement.[1,7] The provision of individualized care and health care encounters that are compassionate and patient focussed, where the patient is helped to navigate the health care experience, with support, understanding and positive interactions, are all characteristics identified to have a profound influence on the patient experience.[1] While it is unlikely that patient volumes will diminish, any applications or tools which are reliable and efficient and will liberate us from having to spend our time being equipment or technology focussed but instead allow us to be focussed on the patient, will lend themselves to enhancing patient care in CT.

AI systems are characteristically associated with some aspect of human intelligence. Examples include, but are not limited to: learning, reasoning and problem solving. The term AI is used to refer to the use of computer systems to perform tasks that normally require human intelligence. Artificial intelligence can be split into two broad types: narrow AI and general AI. The current AI applications commercially available in CT can be considered as Narrow AI [8]. We see applications of this in everyday life: intelligent systems that have been taught or have learned to conduct

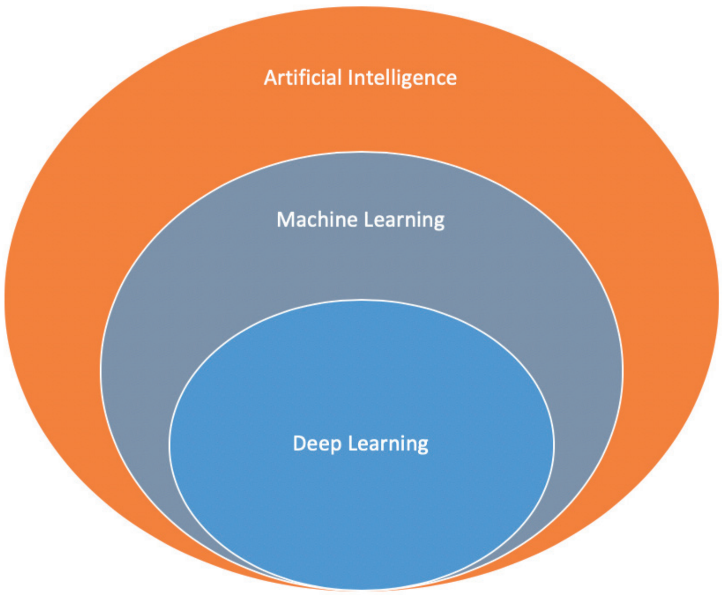

Figure 1: Deep Learning is a subset of Machine Learning (ML) while ML is a subtype of Artificial Intelligence. Artificial Intelligence allows machines to mimic human intelligence.

specific tasks without being explicitly programmed to perform that specific task. Machine intelligence of this kind is found in speech, language and object recognition of a virtual assistant on our mobile phones or on smart devices in our homes. These systems learn or are taught how to do specific tasks, hence the term narrow AI. General AI is very different, it is a representation of flexible or adaptable form of human intelligence, capable of learning how to perform immensely different tasks.[8] General AI does not exist and if or when it will become a reality is a topic of great debate among AI experts.

Machine learning is a subtype of AI where a computer system is fed large amounts of data; and it uses this data to learn how to perform a specific task. The system learns from data inputs to make decisions with minimal human involvement; in other words the system creates the rules or algorithms needed to achieve the task.[8] Machine learning involves the creation of neural networks. Networks of interconnected layers of algorithms, called neurons, that feed data into each other, and which can be trained to carry out specific tasks. Training of these neural networks continue until the output from the neural network is consistent with what is desired, at which point the network will have 'learned' how to carry out that specific task.[8] A further subset of machine learning is deep learning. Training occurs using massive amounts of data, therefore, artificial neural networks are expanded into vast networks with an even greater number of layers. These deep neural networks (DNN) contain multiple layers of mathematical equations with extensive connections trained and strengthened based on the desired output.[2,3] There are different types of neural networks, suited for different applications. For example, recurrent neural networks are well suited to language processing and speech recognition, while convolutional neural networks are more commonly used in image recognition.[8]

Applications of AI in CT

There are a number of current applications of AI in CT which ultimately impact on patient care. The main areas of AI application commercially available are: Patient positioning, image reconstruction, detection & analysis.

Patient Positioning

AI is being used to assist radiographers with patient positioning accuracy in CT. An in room camera, mounted to the ceiling above the patient table, captures patient's dimensions while the patient is lying on the table.[6] The table then moves into the correct position for scanning. The AI task is to position the patient in the optimum position in the gantry based on the selected protocol. Such a tool can shorten set-up times and improve image quality and radiation dose, owing to accurate iso-centric positioning.[6] Images acquired by the camera are evaluated by AI algorithms.[6] These algorithms have learned from a large amount of clinical data comprising patients of difference sizes. 3D modelling of the patient's position and orientation on the CT table is performed, then the system selects the ideal iso-center position.[6] Manual fine tuning can also be performed if needed.

Image Reconstruction

A persistent dilemma in CT is that of lowering dose while optimizing image quality. CT reconstruction

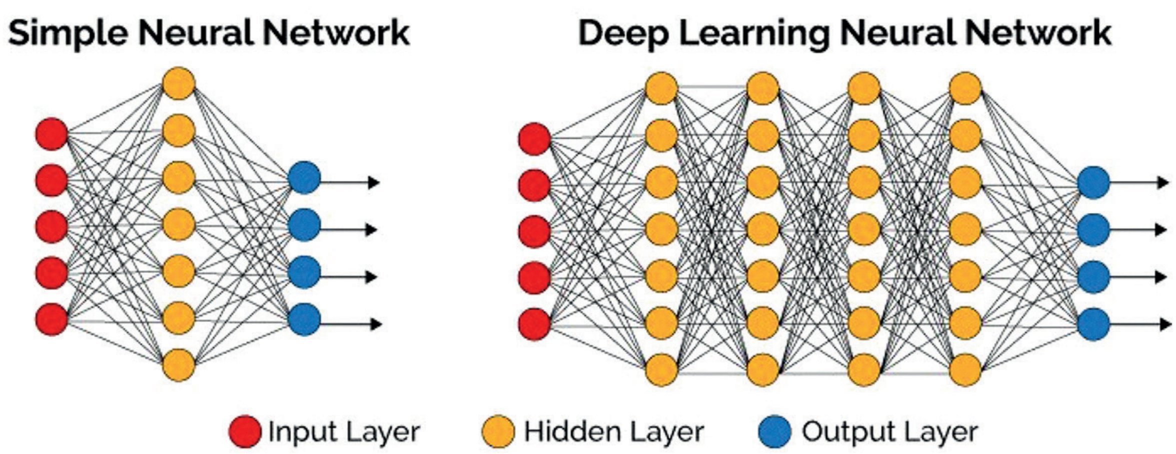

Figure 2. Deep Learning Neural Networks form multiple layers of mathematical equations with extensive connections trained based on the desired output. The ability to learn via a deep neural net gives Deep Learning algorithms the freedom to find the best way to achieve the required task. Conventional algorithms are limited by pre-programmed rules for performing a complex task, however, Deep Learning occurs when a neural network learns from its own intensive training process and develops its own reasoning based on this.[3]

techniques such as Filtered Back Projection (FBP) and Iterative Reconstruction (IR) have their own challenges. FBP requires high radiation doses to produce high quality images. Meanwhile IR requires less dose than FBP but it possesses non-desirable image texture characteristics on the resultant image.[2,3] Additionally, the application of more sophisticated IR techniques such as Model Based Iterative Reconstruction comes at a cost of reconstruction time which is disadvantageous to workflow efficiency and patient throughput.[3] The introduction of AI in image reconstruction results in improving image quality and preserving image texture in low dose images, compared with existing IR algorithms, without workflow compromise. Patient care benefits are related to lower radiation dose, faster patient throughput and improved image quality. Deep Learning Reconstruction (DLR) is trained using high quality target images. The exact target type is vendor dependent. Examples include, high quality FBP Target images[2] and advanced MBIR Target Images.[3] The learning takes place at the factory and the system learns to turn high noise (low dose) input data into low noise images. The specific goal is to differentiate signal from noise and produce images that are "sharp and clear".[3] This is a highly complex task and the machine learning involves an intensive process using vast data inputs, leading to the development of a DLR convolutional neural network (CNN).[3] Once trained the DLR operates in the raw and image domains to efficiently reconstruct images.[3] Scanners with DLR capability usually have three levels of application which allow images to be produced with three levels of noise reduction.[2,3] These settings can be built into the protocol and saved based on Radiologist preference. This makes DLR easy to apply, not requiring additional technologist input. Any application that can be pre-set or not requiring operator intervention, promotes the opportunity for the radiographer to focus on the patient.

Owing to the DLR capability, CT imaging using Ultra High Resolution Scanning (UHR), with 0.25mm x 160 detector elements and 1024 image reconstruction matrix, is now possible with dose neutral imaging. DLR learns to preserve edges and maintain image detail and spatial resolution while improving noise and low contrast characteristics, without the need to increase radiation dose or impede workflow. Scanners also incorporate DLR into auto mA selection which further individualizes the patient's dose based on the dose reduction abilities of deep learning reconstruction.[3] Access to dose neutral UHR CT scanning provides several advantages including the ability to: evaluate small arterial vasculature in peripheral CT angiography[10]; evaluate pancreatic tumors with the ability to assess local tumor invasion; detect solid lesions as well as subtle ground glass opacities in the lung[11,12]; quantification of coronary stenosis[13] and airway measurement[14]. These all have the potential to improve patient outcomes through early, accurate diagnosis of disease.

Apart from the applications described above, deep learning reconstruction is also being used in Spectral CT systems. One vendor uses rapid kV switching technology coupled with AI (Deep Learning Spectral Reconstruction) to optimize energy separation and produce a low noise image. The Deep Learning Spectral reconstruction transforms multi-energy raw data sets (obtained by interleaved acquisition of high kV views and low kV views as the X-ray tube and detector rotate around the patient) into two full high and low energy separated sinograms. Anatomical information contained in a high kV view and a low kV view at a particular location is common to both views; spectral reconstruction uses this high spatial frequency information to its advantage, resulting in energy separation for Spectral analysis with high resolution and low noise properties.[4] The availability of spectral data permits spectral analysis opportunities for: the creation of monochromatic images (increasing iodine contrast-to-noise ratio, decreasing metal or beam-hardening artifacts), the visualization and quantification of iodine and other materials and the characterisation and differentiation of tissue. This data provides Radiologists with greater access to relevant diagnostic information leading potentially to more definitive and confident diagnoses. Spectral imaging also provides the opportunity for increasing patient safety through reduced contrast usage and the omission of unenhanced CT scans.[5] Deep Learning Spectral provides several opportunities for patient care enhancement in CT through improved safety and increased diagnostic capability.

Detection and Analysis

AI is being applied to image interpretation solutions. AI in this area is aimed at workload reduction and efficiency improvements. In some instances AI helps with basic, repetitive tasks, in other instances it helps with more complex interpretative tasks or where reporting is time sensitive or critical. AI solutions currently available have a number of commonalities: Firstly, Classification, where data is automatically prepared and categorized based on exam type then auto selection of the appropriate AI application follows. Secondly, Analysis and Results, where the AI application performs automatic analysis, producing structured results, this can involve identifying and quantifying relevant anatomy and pathologies and placing findings in diagnostic context.[9] Flagging of potentially urgent conditions can also occur. The goal of these platforms is generally to permit faster, more accurate diagnosis and reduce turn-around time for reports to improve patient outcomes. Some clinical applications include:

Chest AI:

AI Applications are aimed at detecting lesions, determining risk (in the case of Calcium Scoring), measuring vessel diameter, detecting emphysema in the lungs, detecting pulmonary emboli, performing segmentation and analysis. AI platforms automatically generate a standardized quantitative report of the data.[9] Using ECG-gated CT scans, the degree of calcification in a patient's coronary arteries can be calculated. Narrowing of the coronary arteries can lead to adverse cardiovascular events. Radiologists can better diagnose the severity of defects, resulting in improved patient outcomes.[15]

Additionally, radiologists generally center their CT interpretations based on the primary clinical indication. The lung AI platform is trained to perform a systematic and equal examination of all areas of the chest, potentially finding lesions in regions that the reader may not have made a priority.[9]

In CT studies containing the lung or a portion of the lung, such as, scans of the chest, abdomen or cervical spine, AI for the detection and prioritization of incidental COVID-19 findings is available.[17] Prioritization of incidental findings of ground glass opacification, a non-specific imaging finding associated with COVID-19 infection, may help in the management of adverse effects of COVID-19.[17] A patient undergoing oncology screening or trauma imaging, for example, but who does not exhibit any COVID-associated respiratory symptoms, will benefit from incidental COVID-19 findings as this information can promote further patient evaluation.[17] Prompt identification of incidental COVID-19 findings will permit sooner treatment or isolation and will help limit the spread of the disease.

Brain & Stroke AI:

AI performance features in this area include: Automatic labelling, visualization and volumetric quantification of segmentable structures from CT images of the brain to provide automated registration and reformatting of data.[16] Other AI platforms, review images immediately after the patient is scanned and informs radiologists of potentially dangerous cases such as intracranial hemorrhages, as this can be life-threatening, therefore the prioritization function is important. This deep learning application helps to reduce turnaround time by analyzing images and increasing radiologists' confidence in decision-making.[15] AI-based automation platforms for stroke analysis are zero-click solutions that use deep learning technology to streamline the workflow for fast results. Deep learning technologies process and deliver images for accurate triage, prioritization and decision making.

MSK AI:

AI Software available include triage and notification software used in the analysis of cervical spine CT images for flagging and communication of suspected positive findings of linear radiolucencies in the bones of the cervical spine identifying patterns compatible with fractures.[16] Also available is quantitative and qualitative analysis in the evaluation and assessment of musculoskeletal disease.[16]

Oncology AI:

Application for viewing, manipulation, 3D- visualization and comparison of medical images from multiple imaging modalities and/or multiple time-points.[16] CT image software is also available for analysis and visualization of Liver CT data. It is designed for assessing liver morphology with automated tools for liver segmentation and measurement.[16]

Conclusion

AI is poised to continue having a significant impact on CT. AI has already been established across three major areas of CT: patient positioning, image reconstruction and image analysis. These applications all have a direct impact on patient care. They result in greater examination efficiency; improvement in patient safety; reduction in radiation dose; enhancement in image quality; and faster, more accurate diagnosis. AI enables increased automation of various activities considered tedious, complex, time sensitive or high-stake; allowing greater focus to be on the patient. As AI development continues, newer, more advanced applications will provide further efficacy and efficiency. The onus will be on Radiographers and other Health Care Professionals to embrace these changes and ensure that they use these opportunities, to provide the quality of care our patients deserve.

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Mrs Suzette Thomas-Rodriguez and Ms Aneesa Ali

Tunisia

Artificial Intelligence and its application in the radiology departments in Tunisia: A route to be defined

THE evolution of technology, the aging of populations and the lack of financial and human resources in health represent a great challenge for the health systems which force it to optimize their resources. Using new technologies, such as Artificial Intelligence (AI), is beneficial for patients and healthcare professionals. By using large amounts of data generated by the different medical imaging methods, AI will allow us to increase our capacity for analysis and decision-making, to improve the way we diagnose, detect, treat, predict a disease and support a patient.[1] In medical imaging, the radiology technologist will participate in the management of AI projects such as improving the workflow, producing high quality images, image segmentation, improving image interpretation, automation of image recording, radiomic analysis (Figure1).

AI and medical imagery in Tunisia

In medical imaging, AI finds a place already ready with the use of digitization. It is now possible to have a diagnosis, which can be, sometimes more precise than a report from a radiologist. But, with the application of this technology in our radiology departments, how can we take advantage of AI to improve patient care? Will our technical work also be transformed? What place will radiology technologists have in this area? Questions that several health committees in Tunisia are trying to answer by developing a roadmap whose purpose is to specify the new responsibilities of radiology technologist, like other health professionals.
In an African country like Tunisia, the use of AI was not new. During the COVID-19 crisis, for example, Tunisian engineers developed, in collaboration with radiology professionals, an open access artificial intelligence tool to help instantly diagnose the disease from simple X-Rays of the lungs thus accelerating screening in regions without medical centers. This online platform has enabled our Tunisian hospitals to detect COVID-19 in record time with an accuracy rate of up to 92% and at low cost (Figure 2).

A Tunisian start-up also succeeded in carrying out a functional characterization of the SARS-CoV2 genes using an AI that it developed in Tunisia and even managed to identify candidate molecules last February (Figure 3). Tunisian radiology technologists are, therefore, among the professionals who directly participate in the success of this technology by the quality of the radiological images they produce daily.

AI committees and roadmap

Committees have been formed to study the impact of AI on the health professions including that of the radiology technologist. In conjunction with recent union movements to improve the situation of paramedical professionals, other working groups made up of former radiology professionals have been brought together to provide ideas on the role of the technologist in the application of AI projects in medical imaging departments. Since this technology has a direct interest in the field of radiology, the place of the medical imaging technologist is important in the planning, execution and quality control of data. The technologist will be responsible for the organization, classification of databases and segmentation of DICOM images (Figure 4).

After some time of reflection and research, the committees concluded that group work is essential in the field of AI. They suggested several actions to change the work of health professionals and at the

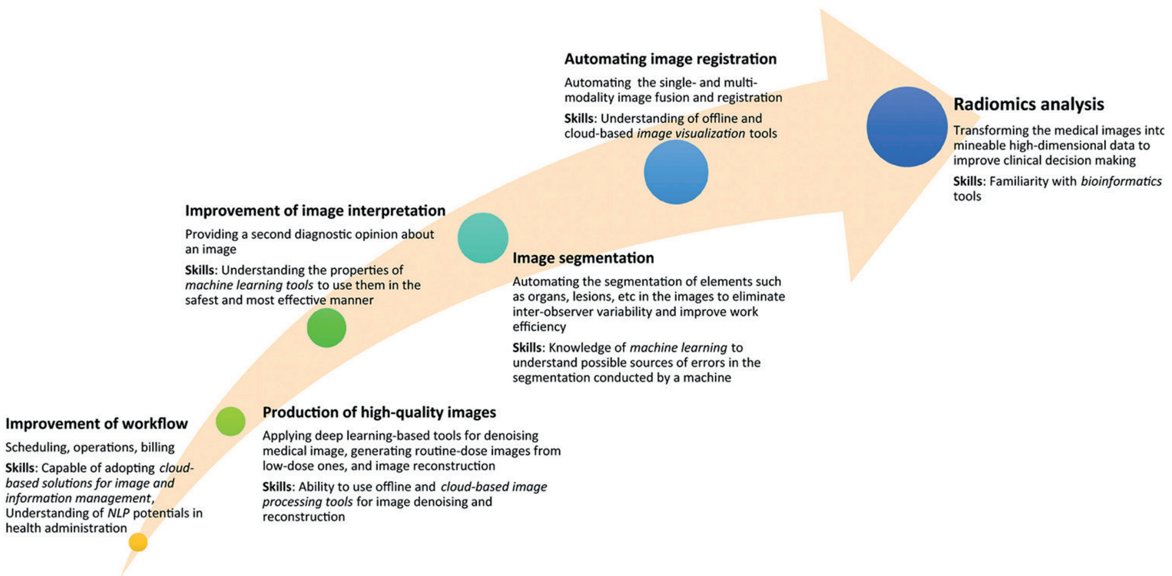

Figure 1: AI areas of impact for medical imaging practice.

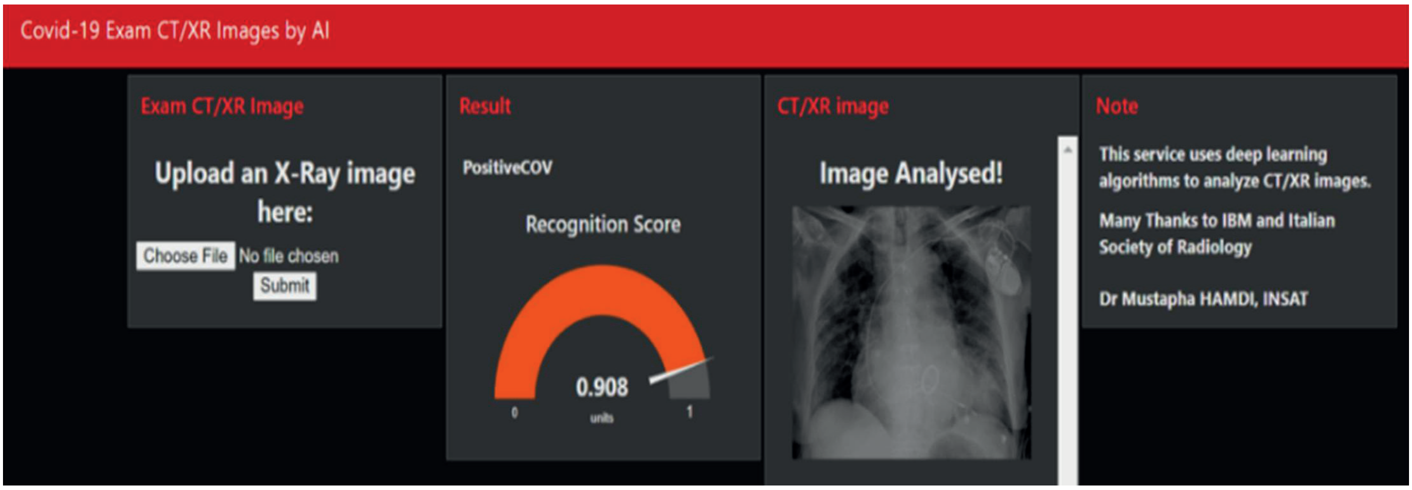

Figure 2: Diagnosis of COVID-19 by AI using radiographs of the lungs performed by radiology technicians.

same time improve patient care. Here are some of the main recommendations:

- Encourage research and strengthen the partnership between students, researchers and industry.
- Strengthen quality control in medical imaging since DICOM images are the basis of several AI projects in health.
- Encourage the culture of innovation among radiology technologists by setting prices and grants.
- Finance AI projects that add value to the quality of radiological examinations.
- Add AI in the academic training of the radiology technologist.
- Add the theme AI in the permanent scientific training during the national congresses.
- Study the possibility of establishing a university path applied to health in the field of AI.
- Introduce radiological protocols based on the automation of technical tasks.
- Collaborate with radiologists to multiply AI projects in radiology departments.
- Continue to strengthen the responsibility for radiation protection for the radiology technician when using AI.
- Sensitize technologists on ethical and legislative rules.
- Privilege informed communication with patients to avoid ambiguity in the use of AI and have their confidence.
- Establish collaboration between foreign health and research bodies to exchange ideas and seek avenues for partnership.

The radiology technologist and the AI

In Tunisia, several discussions are underway for a complete reorganization of the category of paramedics including radiology technologists. The goal is to allow technologists to benefit from the implementation of new technologies, such as AI. New horizons and additional tasks will therefore be added to the technologist's profession.

After committee work, a declaration from the Tunisian Society of Radiology and the Tunisian Association of Radiology Technologists will not be long in coming to raise awareness on important topics related to the use

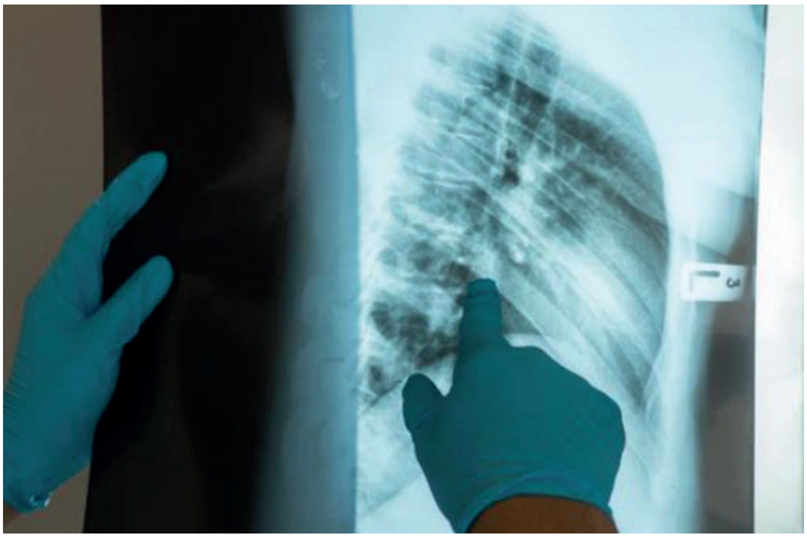

Figure 3: An artificial intelligence tool to help screen for COVID-19.

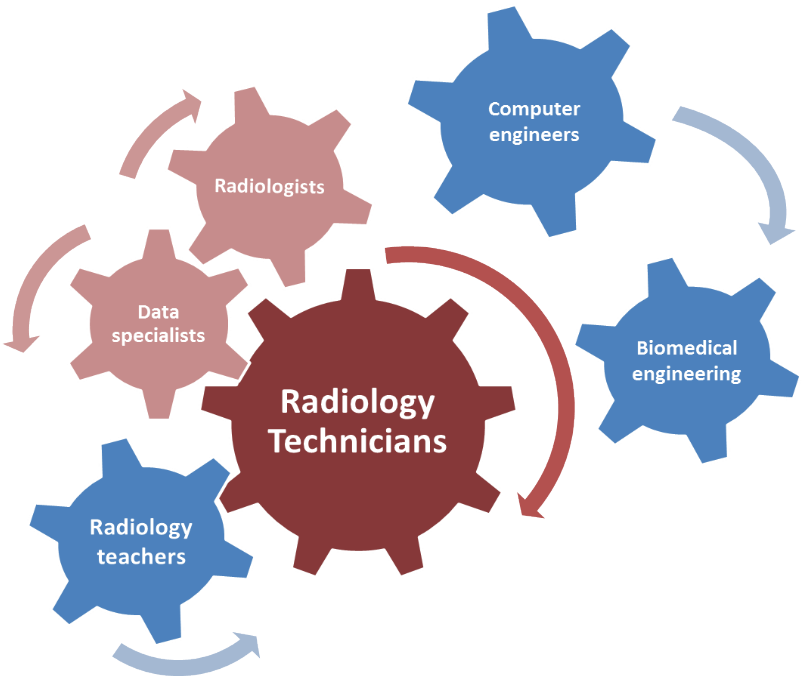

Figure 4:
Technologist's place in an AI project team.

of AI as ethics, technologist responsibility, radiation protection, communication with patients.

Particular attention to an important task for the technologist: the development of radiological protocols is at the heart of the changes caused by AI. Thus, it is essential that clear protocols are developed to support the implementation of new systems and, where possible, quality standards are developed jointly by professionals in imaging and radiotherapy services to support the implementation consistent implementation of proven technologies to high standards.[3]

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Elevating patient care with Artificial Intelligence: Radiographers are essential in elevating patient care with Artificial Intelligence

The UK perspective

Artificial Intelligence (AI), an ever growing field of computer science, working to construct and validate smart machines and smart algorithms that are capable to perform tasks typically requiring human intelligence[1,2], is already here. AI and all its different sub-fields such as machine learning and deep learning have indeed already permeated clinical practice in Medicine, as well as Science and Technology[3-5].

Radiography, both diagnostic and therapeutic, has always been at the forefront of technological innovation and the workforce has built resilience and a unique level of adaptation to and engagement with technological advancements[6], by ensuring research and education follow suit to support the changing practice.

Radiography, both diagnostic and therapeutic, being one of the most technology-enabled professions, is experiencing a groundbreaking transformation in clinical practice because of AI: this includes workflows, patient data management, archiving and storage, patient positioning and image acquisition and planning, motion correction, image segmentation and post-processing but also image interpretation[7-9]. Smart planning tools in current clinical use, for instance, include automated rule implementation and reasoning, modelling of prior knowledge in clinical practice, and multi-criteria optimisation. There are unique features involved in AI that make it perhaps one of the most revolutionary technology advancements our profession will probably, with many claiming this is indeed disruptive innovation, which is trained to learn and organically grow and adapt exactly like the human brain and intelligence does[10].

Like every technological innovation, it is important to ensure it is used as a tool to augment and enhance practice, patient care and safety and quality of imaging, the very purpose of the profession of radiography. Changes in radiography practice brought over by AI remain currently – mostly- isolated in specialist or research centres, but they increasingly start impacting clinical work. These are translated into more standardisation and increased workflow efficiency, but there is now more than ever scope to ensure that the savings in time can be used to improve patient care in many different ways. These can include some of the following:

1. Better communication both between patient and clinical teams but also between the clinical teams; this may include seamless interdisciplinary communication of patient's condition and needs, communication with patient, family and carers and customisation of the approach to respect cultural differences and patient preferences before, during and after the examination.

2. Customised and improved examination experience, including optimal positioning and data acquisition techniques based on patient biometry, gender, age, area of interest and condition, to improve the quality of the imaging examinations, minimise repeats and technical errors from (motion) artefacts and make examinations better tolerated by patients (e.g. AI can reduce the need of breath-holds for MRI scans, correct retrospectively for motion artefacts or even reduce the duration of radiotherapy sessions, if planned using precision medicine[11]).

3. Consideration of fully integrated radiomics and genomics, which would offer a complete picture for the patient but also comparison of findings with patients of a similar profile. These could inform optimal patient management and facilitate improved patient outcomes, allow for more comprehensive holistic, person-centred examinations, addressing the person/patient and not only their condition in isolation. It would also allow the patient to make truly informed choices in relation to acceptance of imaging and treatment,.

4. Optimisation of workflows, to minimise delays in referrals, facilitate quicker turnaround times of reports and more robust results in image interpretation. This could also extend to include same day referral onto further imaging or prompt commencement of treatment pathways. Artificial Intelligence systems could simplify many steps of the complex workflow of radiotherapy such as segmentation, planning or delivery[12].

5. Increased patient safety profiles, with more standardised clinical governance, quality assurance and quality control checks, universal safety indicators, customised to each examination and individual clinical case.

Those who dream of faster workflows and higher throughputs of patients undergoing medical imaging examinations and radiotherapy treatment must not look only to AI for this, as staff burnout and reduced job satisfaction will lurk around the corner to negate any potential benefits. Instead, faster throughput of patients and more efficient workflows can only be assured with concurrent significant investment in advanced education and training into the new technologies of medical imaging staff (for radiographers, radiologists, medical physicists), proportionate staff recruitment and the procurement of high-end software and hardware; otherwise the benefits of AI can quickly evaporate into thin air.

There are many challenges standing in the way of an effective implementation of AI in the UK and other countries[13-15].

The changes in clinical practice of radiography due to AI can already be felt, as described earlier here; however this progress is barely matched by proportionate changes in education and training but also in relevant radiography-led research projects, with few bright exceptions in the UK academia and beyond. Thankfully, but slowly, this trend seems to change and attitudes to shift. It is only through practice-led research and research-informed teaching that AI can be effectively implemented and the fruit of what is now only AI promises can truly materialise for the benefit of the patients and the clinical teams that serve them.

A better-educated - on the basics of AI and patient-centred care- radiography workforce can act as the gatekeeper and identify a faulty or not-properly validated algorithm and highlight when results might not make clinical sense for the patient or examination in question. An up-to-date radiography practitioner can perform regular quality control and quality assurance of AI software and hardware and interpret findings, offering solutions to streamline workflows. A radiographer who is adequately educated to understand AI can also help the clinical validation of this algorithm in practice, as we are after all the workforce that spends more time with the patients in medical imaging examinations.

Research stemming from within Radiography will also support the integration of high-quality, truly validated, AI-supported medical imaging and treatment with patient-centred care. It will also ensure it brings the patient voice into the equation to help inform the design of medical imaging equipment and processes. In this role the radiographers will act not as ambassadors or advocates but will ensure the patients participate as equal research partners into the design of the equipment and the mapping of the processes that will be used for their imaging examination.

Participation of radiographers in national and international consortia and decision-making committees for AI is not currently really representative of the workforce size or scope or indeed of its unique role in managing and facilitating this transition to a future with AI. Unfortunately this means that there is a real danger that we could miss out on the opportunity to inform the future of our practice, education and research in this field if we are not part of the decision making process.

Some progress to address some of these challenges in the UK is currently in place, which is reassuring, but this momentum has to intensify.

There is currently a small but increasing number of postgraduate and CPD educational initiatives on AI offered by UK Universities, but these need to multiply and allow more flexibility for the workforce that is currently practicing but also for current students and future/imminent graduates who will be faced with a much different reality than their predecessors.

There is a small but increasing number of UK academic conferences, seminars and online resources focused on AI and aimed at raising awareness of radiographers on AI topics, and allowing discussions of contemporary issues in this field. Many of these resources are also provided by Health Education England and the Department of Health to support the training of the workforce, inline with the Topol review recommendations[16]. More collaboration between clinical practice and academia will ensure these educational provisions will help align theory with practice and make training relevant and meaningful to the workforce.

Some small isolated local (often single-site) research projects on AI led by UK radiography academics are in place but we need a robust framework, which will allow large, multidisciplinary teams to form and work together on big project grants and academic and research radiographers to have enough notice and support to collaborate towards common targets and priorities for the profession, as identified by the Society and College of radiographers research priorities for the profession[17]. A mapping of current AI projects in the UK by a central agency would be essential to ensure there is coordination and we avoid unnecessary duplication of effort; whose role this might be, remains yet to be answered.

Lobbying and inclusion of radiographers in the AI planning and decision-making committees will be vital to ensure a proportionate representation of our profession in a future with AI. This agenda is currently being supported by our professional body, the Society and College of Radiographers, who have fostered initiatives to support a review of the current education and careers framework (ECF) with the inclusion of many experts from different modalities in the field and with AI as a key theme, among other priorities.

Artificial intelligence is just a tool and subject to regulated and controlled use it can really revolutionise not only medical imaging and radiography but also all fields of healthcare, for the benefits of the patients. Like any tool, its use has to be validated, quality-controlled, subject to the same scrutiny and ethics, as previous healthcare technologies for it to be deemed safe for use and clinically meaningful. Patient input will be vital in the outputs of AI software and hardware to ensure it serves patient needs and allows for customisation of radiography service. Education and research in radiography will need to accelerate to ensure the workforce is equipped with what they need to make the most out of this amazing new opportunity and to minimise any risks that may arise now and in the future.

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EUROPEAN SOCIETY OF RADIOLOGY

Artificial Intelligence – A challenge and an opportunity for the radiography and radiology professions

By Adrian Brady

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He graduated in medicine from University College Dublin in 1984. After pursuing specialty training in internal medicine, he began training as a radiologist in Dublin in 1987. In 1991, he moved to Canada for further training in gastrointestinal and abdominal imaging and intervention, at McMaster University Medical Centre, in Hamilton, Ontario.

He worked as a staff radiologist in the Wellesley Hospital, Toronto, and Assistant Professor at the University of Toronto from 1992 to 1995, returning to Ireland in 1995 to take up his current position, where he works as a general and interventional radiologist.

Dr Brady has served in many leadership positions within Ireland and Europe, serving as Dean of the Faculty of Radiologists, RCSI (the equivalent of President of the National society and head of national radiology training) from 2010 to 2012.

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42 DEPENDING on your viewpoint, this apparently simple number may signify many different things: the atomic number of molybdenum, the sum of the first six positive even numbers, the number with which God creates the universe in Kabbalistic tradition. Perhaps it is best known in modern culture as the "Answer to the Ultimate Question of Life, the Universe and Everything", calculated over 7.5 million years by the enormous supercomputer named Deep Thought (in Douglas Adams' 'The Hitchhiker's Guide to the Galaxy'[1]). Sadly, no-one knows what the question is.

Adams (and his readers) had much fun with this answer/question difficulty, but underpinning the entire theme is a truth: much of our lives is governed by mathematics. As Artificial Intelligence develops, and increases its involvement in healthcare, this digitization of who we are and what we do will accelerate.

For professionals such as radiographers and radiologists, this may not be as large a transition as for some other healthcare workers. Our working environments are already physics-rich, and heavily dependent on our technical knowledge and expertise. We work on a daily basis with human-digital interfaces and large amounts of digital data. Our specialties are thus ideally positioned to reap the benefits of current rapid developments in AI application to medicine, and we have a great opportunity to be in the vanguard of informatics and AI developments in medicine. We are already in the business of generating, manipulating and interpreting large amounts of (fundamentally digital) data. It's not a huge step for us to expand our horizons to encompass the exciting developments in machine learning, data mining and AI application which are emerging on an almost-daily basis.

Peruse the contents pages of any current significant radiology or radiography journal; one of the most-represented categories of papers is informatics and AI. This is not a temporary flash in the pan. We should not assume that after the first flush of papers, AI will diminish in importance, and things will go back to where they were before. AI is already changing what we do and how we do it, and this change will accelerate. Many of the time-consuming tasks we perform can be done more rapidly and with greater sensitivity and efficiency by AI tools. AI is already capable of contributing to our work in a multitude of ways. Lesion detection and segmentation can be done (at least in some radiologic studies) by algorithms. Imaging protocol selection can be done in real time by AI (e.g. findings detected automatically on early sequences of an MR study can automatically lead to parameter or sequence adaptation later in the study to optimise the imaging). Workflow can be changed and improved by AI (e.g. identifying patients more likely not to keep an appointment, and automatically reminding them).

Some of these innovations are straightforward, and unequivocally welcome. We may be more ambivalent about others. Many available software packages are better than we humans are at identifying and highlighting lung nodules on

CT. However, that doesn't mean these AI tools are better than we are at performing the higher-level synthetic tasks of interpreting the meaning of these nodules and formulating rational differential diagnoses. The value of AI in the future is likely to be in assisting us by drawing our attention to findings, and providing us with information we might not have perceived; there will still be room for, and a definite need for human involvement in interpretive tasks.

AI isn't magic, it's maths. While much of the natural world, from fundamental forces to cosmology, is governed by mathematical relationships and rules, few of us would be willing to cede decision-making about the important things in our lives to such rules. Although it may impress with its speed and efficiency, AI is not an empathic organism, sensitive to the emotional needs of others, or conscious in any meaningful way. For those attributes, we need humans. We must not lose sight of the basic fact that AI algorithms are mathematical functions, designed (or self-designing) to fulfil pre-determined functions or achieve programmed outcomes. It's easy to imagine an AI programmed to eliminate cancer in humans. The most-direct, simplest and fastest way to achieve that goal is to eliminate the human race, but that's probably not what the algorithm's designers wanted or what the population on which the AI is deployed might welcome. Just because an outcome is true to the mathematics of the AI doesn't mean it's desirable, and steadying human hands will always be needed, if AI is to prove a boon to humanity.

So, AI is versatile, clever and capable of things we humans can't do. But it's not a replacement for us, and humans must remain in control of AI development and use. There are fundamental ethical principles that should underpin AI, some of which have been elaborated upon in the multisociety radiology society statement on the ethics of AI in radiology, published in 2019[2], and in other related papers[3,4]. Also in 2019, the EFRS and ESR jointly published a statement on patient safety in medical imaging[5]. Among the aspects of safety we considered in that paper was data security, the need to ensure that imaging data access is only provided to appropriate individuals, and that patient consent is always ensured for any use of their personal data. AI opens up a plethora of potential new uses for patient data, for clinical work, software development, data mining and radiomics and commercial development. It's incumbent on those professionals such as radiographers, radiological technologists and radiologists who are central to the creation, manipulation and interpretation of that data to ensure that it is only used for the benefit (direct or indirect) of those whose information we are privileged to use, and always with their consent[6].

In terms of patient safety, the most-minimal directive is the "requirement that all possible efforts should be made to ensure patients are no worse off after their interaction with radiographers and radiologists than before"[7]. Naturally, we always seek to go far beyond this basic limit. AI offers wonderful opportunities for patients, and for professionals to improve the quality of the services we offer. It also carries risks, which can best be mitigated by keeping knowledgeable professional humans in charge[6]. Radiographers, radiological technologists and radiologists are ideal intermediaries in this new world, able to harness our clinical knowledge and humanity and our technological expertise to benefit and protect our patients. So, to return to that fountainhead of wisdom, Douglas Adams: "Don't Panic"[1].

It's a pleasure and privilege to be able to make this contribution on behalf of the ESR to the ISRRT annual special edition on the occasion of World Radiographer's Day, and to reflect on and emphasise the vital role our professions jointly fulfil in patient care, safety and welfare.

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EUROPEAN FEDERATION OF RADIOGRAPHER SOCIETIES

Medical Imaging and radiotherapy radiographers have a responsibility to ensure Artificial Intelligence is used to elevate patient care: The views of the European Federation of Radiographer Societies

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RADIOGRAPHERS have always been the patient facing element of medical imaging and radiotherapy, at the intersection of technology and patients. As a profession, radiographers have always evolved and adapted to emerging technologies; this has not changed during the artificial intelligence (AI) "revolution" but perhaps the scale and speed of change has increased.

As healthcare professionals it is essential that radiographer practice is evidence-based. Recent high-profile retractions from New England Journal of Medicine (Mehra et al., 2020) and Lancet (Mehra et al. 2020) related to the COVID-19 pandemic reinforce the requirement for thorough and robust evaluation of healthcare, with transparency. AI, even in a decision support role, can have an impact on patient outcomes and needs to be evaluated with similar diligence to medication. "Algorithms are the new drugs" and can have a profound impact on care decisions (Harvey, 2017). A recent systematic review highlighted the poor-quality published research underpinning many AI healthcare interventions (Nagendran et al., 2020) and we need to assure ourselves and our patients that we are providing safe and effective care. That is not to say that we should dismiss all new interventions, but rather introduce changes to practices in a controlled and systematic way. Radiographers need to be able to critically evaluate and appraise all interventions in medical imaging and radiotherapy, to ensure that patient outcomes are improved where AI is introduced into clinical practice.

Are radiographers involved in the design and implementation of AI in clinical practice? Material arising from medical imaging industry partners is often solely focused on the impact on radiologist workflows and experience. Without radiographers obtaining high quality diagnostic examinations there is, however, no data for radiologists or algorithms to interpret! It is just essential that radiographers contribute to such developments. The recent joint statement of the International Society of Radiographers and Radiological Technologists (ISRRT) and the European Federation of Radiographer Societies (EFRS) on Artificial Intelligence and the Radiographer Profession, concluded that:

> *"… of critical importance that radiographers, as medical imaging and radiotherapy experts, must play an active role in the planning, development, implementation, use and validation of AI applications in medical imaging and radiation therapy, reinforcing the need for the technology to be targeted to the most pressing clinical problems."*
>
> *(SRRT & EFRS, 2020)*

Various algorithms are being developed and marketed that recreate "high quality" CT and MRI images with reduced radiation dose or scan time using algorithms to improve the signal to noise ratio. But, as radiographers, are we assured that the information that we are generating is a true representation of the patient we are examining and not an "average" patient? How do we know a rare or significant abnormality has not been replaced on the imaging with what the algorithm expects or anticipates being there? The issue of false negative diagnoses, when AI reconstruction algorithms are used, is a growing concern and one that requires further research before these interventions are deployed into routine clinical practice.

Public and patient involvement (PPI) or patient, public and practitioner partnerships (PPPP) within medical imaging and radiotherapy (SCoR, 2018) should underpin all we do, including the development and implementation of AI into our practices. PPI highlights the need for true patient involvement at the discussion and planning stage of any service improvement. This is something that has been emphasised by the EFRS in recent years. Patient representation can often be tokenistic, even if well intentioned, so moving to an advocacy model of patients at the heart of planning and service delivery will ensure trust and engagement for subsequent data collection and improvement of any models. Figure 1 highlights the key stakeholders in any 'partnerships' related to the development and implementation of any clinical service delivery interventions.

Importantly for AI, PPI or patient / practitioner partnership for both medical imaging and radiotherapy provides profession-specific materials that can be used for values-based practice (VBP) for AI. The education and training of radiographers in VBP, facilitates engagement in shared evidence-based decision-making with their patients, using dialogue about values (SCoR, 2018). This connection to our values, our patients, and their needs, is key to how we continue to be the trusted professionals, and to be trusted other professionals and decision-makers, by in the era of AI in healthcare.

As diagnostic and radiotherapy radiographers, the gatekeeper between referring clinician and patient radiation dose, will we continue to ensure that imaging and radiotherapy is optimised? It is likely, for the foreseeable future, that AI will provide "suggestions" for protocol optimisation, but the radiographer will be responsible for delivering the radiation dose to the patient. As radiographers, are we aware of how these "suggestions" are developed? The 2019 American Society of Radiologic Technologists (ASRT) survey found that radiographers had mixed familiarity with AI features on their equipment; however, a majority were confident it functions correctly and felt results were trustworthy (ASRT, 2019). Radiographers need to be aware of, and fluent in, the research that underpins these tools. A useful analogy is the Boeing 737 tragedies; a modification was made to the aircraft that allowed pilots to "feel" like they were flying a 737, unaware that a sensor had been changed. What safeguards are in place to ensure that scan planning, image acquisition, or contouring in radiotherapy, is appropriate? These technologies are used to enhance clinical decision-making.

As radiographers we need to be improved on improving the health of all, reducing not reinforcing healthcare inequalities. Algorithms used to predict and anticipate imaging demand are trained on healthcare records and previous experience. For example, algorithms can predict non-attendance for screening mammography appointments. So, how should this information be used – to "double book" clinics to ensure maximum use of limited

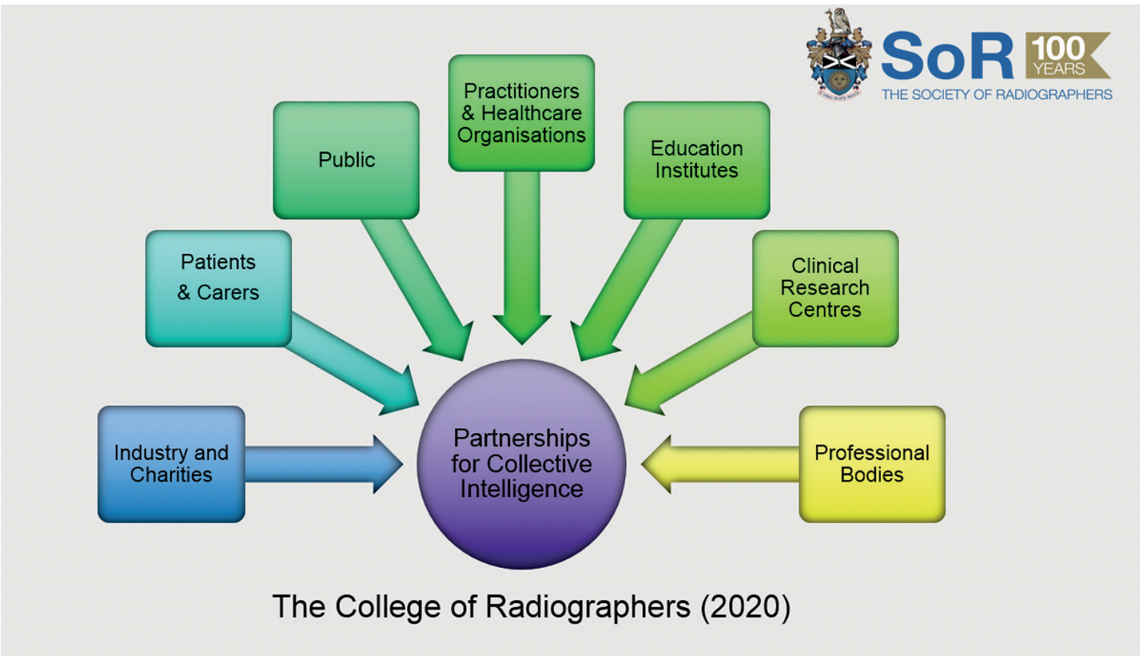

Figure 1: The importance of partnerships in all developments related to clinical service delivery (College of Radiographers, 2020).

diagnostic capacity, or to further engage with potential non-attenders? If the sole measure of imaging is efficiency and the numbers seen, is this reinforcing existing inequality? Patients in hard to reach groups, lower socioeconomic status, those with mental health issues, have historically not engaged with health prevention and promotion; by delegating decisions on attendance to an algorithm do we, as radiographers, allow these biases and inequalities to be entrenched and reinforced?

It is also crucial that radiographers understand and can explain to patient how their data could be used, benefits to themselves and others, ensuring informed consent is obtained and compliance with data protection laws ensured. Moving forward these concepts and experience will need to be embedded in radiographer education, from pre-registration training to postgraduate education and continued professional development. This is echoed by the EFRS and the ISRRT:

> *"The optimal integration of AI into medical safety, clinical imaging and radiation therapy can only be achieved through appropriate education of the current and future workforce and the active engagement of radiographers in AI advancements going forwards."*
>
> (ISRRT & EFRS, 2020)

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