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Volume 34 | Issue 01 | Spring 2024

IPEM
Institute of Physics and Engineering in Medicine

SCOPE

A MAN'S WORLD

Striving for equity, diversity and inclusion

RADIATION PROTECTION

The evaluation of a 3D cone beam fluoroscopy system

ARTIFICIAL INTELLIGENCE

Opportunities and challenges for AI in nuclear medicine

THE ENVIRONMENT

An investigation into how we can reduce our carbon footprint

CLINICAL ENGINEERING

Electrical safety and the testing of medical equipment

CHAIR OF IPEM SCOPE EDITORIAL ADVISORY BOARD

An inclusive workforce

Usman Lula outlines the content in the latest issue, including diversity and equity, AI in medical physics and clear communication.

Welcome to the first *Scope* issue of 2024! As we step into a new year, brimming with fresh resolutions, we are excited to embark on a journey of exploration and enlightenment with you.

Our cover story (p.14) delves into the Matilda Effect, shedding light on the imperative of levelling the playing field within STEM. From educational pursuits to career advancement, we underscore the significance of amplifying the voices of under-represented groups. Central to this endeavour are STEM Ambassadors – catalysts for change who challenge stereotypes, advocate for diversity and foster engagement in STEM among females and minorities.

The pursuit of a diverse and inclusive workforce is not just a goal but a prerequisite for organizational success and the delivery of exemplary care.

While our usual Big Debate takes a backseat in this issue, we are thrilled to present our regular "Member Profile" featuring Dr Kate Bryant. Join us as Dr Bryant offers insights into her daily routines, joys, challenges, requisite skill sets, and more. Flip to page 21 for an exclusive glimpse into her world.

In a previous issue, we teased an upcoming series on AI within the realms of medical physics and clinical engineering. In this edition, we unveil another instalment of our AI series (p.26), this time focusing on nuclear medicine. Lead Physicist Richard Meades offers a comprehensive analysis of the opportunities and challenges inherent in this dynamic field.

> A diverse and inclusive workforce is not just a goal but a prerequisite for organizational success

Gender-dependent radiotherapy is a fascinating, eye-opening and thought-provoking feature (p.36), bringing clarity on issues with far-reaching implications for equity in conducting experimental research and patient care access.

Clear communication lies at the heart of effective scientific dissemination. Dr Sharon Ann Holgate, a distinguished science writer and broadcaster, graciously shares insights into her latest work, *Communicating Science Clearly*. Discover the essence and contents of this invaluable resource, poised to enrich your understanding of science communication on p.54.

We wish you an enjoyable read and look forward to your continued engagement.

Usman Lula

Usman Lula
Chair of IPEM Scope EAB

FEEDBACK

Shape the direction of Scope magazine

Our dedicated *Scope* Editorial Advisory Board, including Rob (our Professional Editor) and Sean (IPEM Office) convene quarterly to curate a diverse array of content tailored to our readership's interests.

Throughout our discussions, your readership remains our compass, guiding every single decision we make. We invite you to share your ideas, feedback, and potential contributions, as your input is invaluable to our collective efforts.

We value your input. Do you have any ideas, feedback, or potential contributions that you believe would enhance *Scope* magazine? If so, we invite you to reach out to us – our contact details are on page 4 . Your insights are invaluable in shaping the direction of *Scope* magazine.

IPEM
Institute of Physics and Engineering in Medicine

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COVER FEATURE

> Women outnumber men in lower-tier roles, whereas men predominate in senior positions across the NHS, showing that more work needs to be done to achieve equity, diversity, and inclusion at all levels of the NHS. This may be preventing some STEM graduates from applying for Clinical Scientist or engineering jobs in the NHS.

***Virginia Marin Anaya**, Clinical Scientist* **page 14**

UPFRONT

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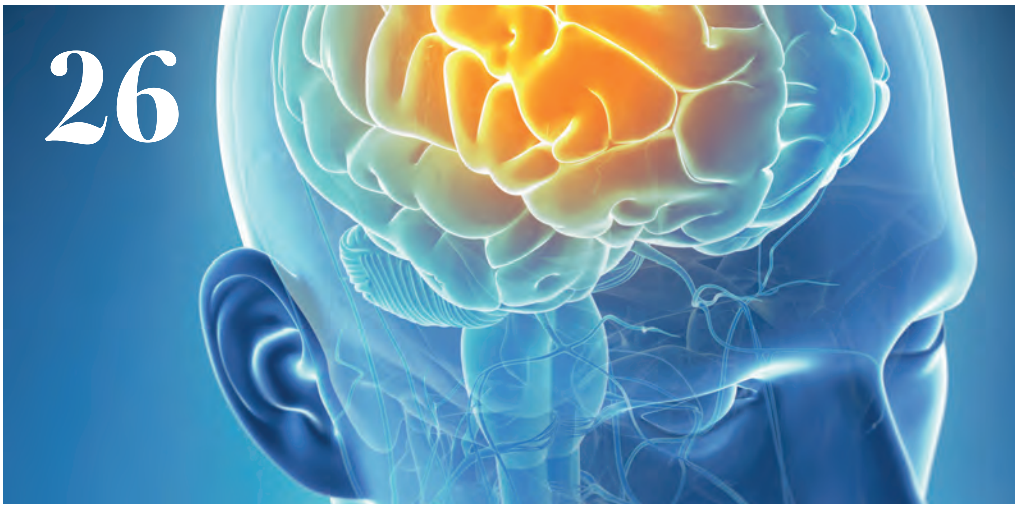
GENERAL



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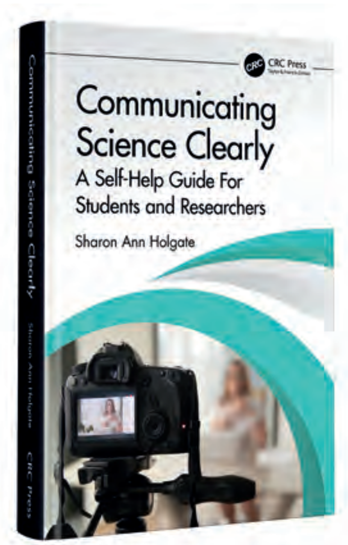

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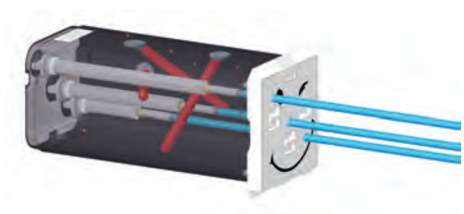

RUBY Base Phantom

Perform integrated tests of the entire treatment chain from imaging to planning and verification with one basic phantom.

Add and expand QA capabilities when needed using a variety of exchangeable, application-specific inserts.

RUBY Head Phantom

Designed specifically for the increasing number of stereotactic deliveries that are performed with head shells on couch extensions.

The realistically-sized RUBY head phantom will accommodate all the inserts and has been successfully tested with the Brainlab as well as the Encompass (QFix) mask systems.

RUBY inserts

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UPFRONT

COMPUTERISED DECISION SUPPORT SYSTEM

Reducing high-risk drug combinations

A multicentre study has shown that tailoring a computerised decision-support system (CDSS) to the intensive care unit (ICU) environment significantly reduced the number of high-risk drug combinations administered to ICU patients.

It also improved monitoring ICU patients when avoiding such combinations was not possible and reduced the length of patients' stay in the ICU.

"Not more, but fewer and more relevant alerts by a CDSS make such a system more valuable for healthcare providers and patients," said Amsterdam UMC's Professor of Medical Informatics Ameen Abu-Hanna, the study's principal investigator.

CDSSs are used to alert ICU physicians about potentially risky drug combinations.

These systems warn the physicians through alerts during drug prescribing. However, these systems are not properly tailored to the ICU, leading to an abundance of not clinically relevant alerts.

Research shows that more than 80% of alerts for potentially risky drug combinations are dismissed by ICU physicians. This diminishes the value of CDSS and compromises patient safety.

"Patients in the ICU are critically ill and are often treated with concomitant drugs. At the same time, ICU patients are extensively and continuously monitored. Therefore, it is important to tailor the CDSS to the ICU environment to prevent alert fatigue and improve patient safety in the ICU," said Assistant Professor and co-author, Joanna Klopotowska.

The authors state tailoring a CDSS to the ICU environment improves patient safety. By alerting only where it matters, the ICU physicians were able to better recognise the dangerous drug combinations.

This approach can also be valuable for other groups of patients, such as neonatology, paediatrics and oncology. At the moment, many hospitals use CDSSs without customisation to their specific patient groups, and the systems' effectiveness is seldom scrutinised.

bit.ly/3SyQF3T

MACHINE LEARNING

TISSUE CONTAMINATION DISTRACTS AI MODELS

In a new study, scientists trained three AI models to scan slides of placenta tissue to detect blood vessel damage, estimate gestational age and classify macroscopic lesions.

They trained a fourth AI model to detect prostate cancer in tissues collected from needle biopsies. The scientists exposed each one to small portions of contaminant tissue that were randomly sampled from other slides. They then tested the AIs' reactions.

Each of the four paid too much attention to the tissue contamination, which resulted in errors when diagnosing or detecting vessel damage, gestational age, lesions and prostate cancer.

"We train AIs to tell 'A' versus 'B' in a very clean, artificial environment, but, in real life, the AI will see a variety of materials that it hasn't trained on. When it does, mistakes can happen," said corresponding author Dr Jeffery Goldstein.

"Our findings serve as a reminder that AI that works incredibly well in the lab may fall on its face in the real world. Patients should continue to expect that a human expert is the final decider on diagnoses made on biopsies and other tissue samples."

bit.ly/3Sb2Li4

IMAGE: GETTY

CANCER RESEARCH

Magnetic resonance imaging during proton therapy

A scientific prototype for MRI-guided proton therapy was inaugurated in Dresden in January.

The hope is to monitor cancer patients during their radiation treatment using real-time MRI imaging and to significantly improve the targeting accuracy of proton therapy.

The prototype, developed by a German research group led by Professor Aswin Hoffman, combines a full-body MRI machine that rotates around the patient for real-time imaging and a proton therapy system.

This was a technological challenge as both the MRI device and the proton radiation system work with magnetic fields that interact with one another and influence the quality of the imaging as well as the proton beam application.

Having already demonstrated the technical feasibility of simultaneous radiation and imaging using a prior prototype, the research group can now utilise the new system for the first time.

"This new prototype with integrated full-body MRI makes it possible to visualise moving tumours using high-contrast real-time imaging. Our work aims to develop a technique to irradiate tumours only when they are hit reliably by the proton beam," said Hoffmann.

"The MRI device, which can rotate around the patient, enables us to use innovative types of patient positioning for proton therapy in both lying or in upright positions."

bit.ly/42b2Xma

REGULATION

IPEM WORKING WITH THE HCPC

A group of professional bodies, including IPEM, has been collaborating with the Health and Care Professions Council (HCPC) to advocate for the interests of members.

IPEM has been represented on the liaison group since 2022, with Dr Jemimah Eve, the Director of Policy and Impact, attending.

Dr Eve said: "I want to update all our HCPC registrants on the work we have been carrying out via the liaison group, so they can see how we have been working on their behalf."

A project to overhaul the fitness to practice (FtP) process is nearing completion. Procedural changes have been introduced in order to reduce the backlog of cases and allow the HCPC to hit its KPI targets.

Although there has been a sustained trend of increasing referrals, Clinical Scientists remain the second-smallest proportion of all FtP cases. Alongside improved efficiency, the HCPC has also reviewed all their communications around FtP in a "tone of voice" overhaul, and new communication templates were rolled out from the autumn.

NEWS IN BRIEF

CAR T cell therapy

The development of any type of second cancer following CAR T cell therapy is a rare occurrence, as found in an analysis of more than 400 patients treated at Penn Medicine. More than 30,000 patients with blood cancers in the US – many of whom had few, if any, remaining treatment options available – have been treated with CAR T cell therapy since the first such therapy was approved in 2017. Some of the earliest patients treated in clinical trials have gone on to experience long-lasting remissions of a decade or more.

go.nature.com/47JgMtf

Ultrasounds and preterm births

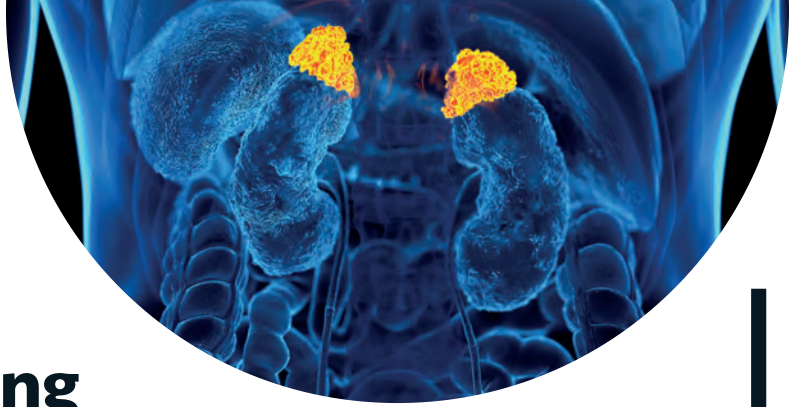
Researchers have developed a way to use ultrasound to predict whether a pregnant person is at risk of delivering a baby prematurely. The new method – the result of more than 20 years of collaboration between researchers in nursing and engineering at University of Illinois Chicago and University of Illinois Urbana-Champaign – measures microstructural changes in a woman's cervix using quantitative ultrasound. The ultrasound method works as early as 23 weeks into a pregnancy, according to the research.

bit.ly/47RktwK

White blood cell tracker

A researcher team has designed and tested a device that quickly counts a person's white blood cells with a single drop of blood, similar to the way in which glucometers rapidly scan for blood sugar levels. The CytoTracker Leukomete is designed to quickly aid the detection of elevated or reduced white blood cell counts. A high or low white blood cell count may indicate the intensity of an infection, the presence of life-threatening conditions such as sepsis, or determine how patients are responding to chemotherapy and psychotropic drugs.

bit.ly/3OfEmaI



NUCLEAR MEDICINE

Diagnosing adrenal gland disorder

A novel imaging approach – 68Ga-pentixafor PET/CT – has been shown to accurately identify sub-types of primary aldosteronism (an adrenal gland disorder), outperforming traditional methods for diagnosis.

In the study, 123 patients with adrenal micronodules identified by adrenal CT were examined using 68Ga-pentixafor PET/CT, and 104 patients who underwent surgery or successful adrenal venous sampling were included in the analysis.

Nuclear medicine physicians evaluated the 68Ga-pentixafor PET/CT data for sensitivity, specificity and accuracy of visual analysis. This was compared to adrenal CT and adrenal venous sampling results.

68Ga-pentixafor PET/CT showed superior sensitivity, specificity and accuracy (90.2%, 72.7% and 86.5%, respectively) in identifying surgically eligible primary aldosteronism patients compared with adrenal CT (73.1%, 53.8% and 68.3%, respectively).

It was also able to predict surgical outcomes better than adrenal venous sampling (82.4 % vs. 68.86 %).

"The significance of this work lies in its potential to change how we diagnose and treat primary aldosteronism patients with tiny adrenal nodules. For patients, this means an improved chance of getting the right treatment, especially when it comes to deciding whether surgery is necessary," said Li Huo, Chair in the Department of Nuclear Medicine at the Chinese Academy of Medical Sciences.

bit.ly/48Nkzaf

CLINICAL TECHNOLOGIST TRAINING SCHEME

Exam success for trainees

The latest cohort on IPEM's Clinical Technologist Training Scheme (CTTS) have successfully passed their course.

The CTTS has earned a strong reputation in the sector, offering a robust, externally validated education and training framework for clinical technologists, and ensuring a workforce fit to practice.

Successful completion of the CTTS sees graduates awarded IPEM's Diploma in Clinical Technology and opens a route to joining the Register of Clinical Technologists (RCT).

The 11 trainees who recently completed the course and were awarded their Diploma in Clinical Technology included:

Katherine Aktemel, NHS Greater Glasgow and Clyde
Jade Collins, University Hospital Southampton NSH Foundation Trust
Brian Maclachlan, NHS Greater Glasgow and Clyde
James Nelson, NHS Lothian
Rizwan Ali, University Hospitals of North Midlands NHS Trust
Aimee Ellis, NHS Greater Glasgow and Clyde
Ethan Armstrong, Oxford University Hospitals NHS Foundation Trust
Graeme Henderson, Belfast Health and Social Care Trust
Jordan Summers, South Tees Hospitals NHS Foundation Trust
Wongani Chavula, Hull University Teaching Hospitals NHS Trust.

Applications for the next intake of the course are due to close on 31 March.

ipem.ac.uk/learn/clinical-scientist-training

IMAGES: ALAMY/SCIENCE PHOTO LIBRARY

CANCER SCREENING

DIGITAL PATHOLOGY CLEARED FOR USE

New research has led to the UK government approving the use of digital pathology to help speed up analysis of cancer screening samples.

The use of this technology will result in faster reporting of people's samples, particularly in bowel, breast, lung and cervical cancers.

Digital pathology is the use of automated slide scanners to digitise the histopathology process.

Results are reported on computer workstations as opposed to a conventional microscope, enabling pathologists to report samples remote from the laboratory producing slides.

This process makes sharing samples easier, helping to reduce risk of loss or damage of samples.

It also mitigates the need for pathologists to be present in hospitals, as they can review the slides remotely. Digitising the slides might also allow computer algorithms to help improve pathologists' performance in the coming years.

bit.ly/48OmMSC

IMAGE: ©UNIVERSITY OF WARWICK

STEM AWARDS

ACCOLADE FOR IPEM MEMBER

A clinical technologist was victorious at the West Country Women awards.

Leanne Moore, a clinical technologist in the Radiotherapy Physics Department at University Hospitals Plymouth NHS Trust, won the Women in STEM category.

The awards celebrate the achievements of exceptional women across the region.

Leanne, an Associate Member of IPEM who is on the Register of Clinical Technologists, was one of three women competing for the prestigious Women in STEM award.

She said: "My immediate reaction to winning was complete shock and totally overwhelmed. I feel privileged to have been part of the process and so grateful of the support and encouragement from my colleagues in the radiotherapy physics team at Plymouth.

"I hope this will help promote the profession of dosimetrists to the wider community and I will continue to shout about the work we do under the umbrella of science in healthcare."

INNOVATION

US President awards IPEM member

President Joe Biden has awarded the US' highest honour for technological achievement to a member of IPEM's ebooks advisory board.

Dr Rory Cooper was presented with the National Medal of Technology and Innovation for his outstanding contributions to engineering science during a ceremony at the White House.

At the ceremony, President Biden: "You are all so damn impressive. You're literally changing the world for better."

Dr Cooper is a Founding Director of the Rehabilitation Research and Development's Human Engineering Research Laboratory (HERL) at the University of Pittsburgh, where he oversees and conducts research to support disabled veterans and other individuals with mobility impairments.

HERL holds 25 patents, and their inventions are used by more than 250,000 people every day.

Dr Cooper is a member of the IPEM/Institute of Physics Publishing ebooks advisory board. Around 30 ebooks have been published in the series since they began in 2017 and almost as many are currently in the pipeline.

Dr Cooper has used a wheelchair since an accident in 1980, when he was serving in the Army, left him paralyzed from the waist down.

Together with his research team, he has developed several innovations to overcome mobility challenges, including assistive robotic manipulators, a wheelchair that can climb curbs and uneven terrain, microelectrode brain-machine interfaces, transfer biomechanics, and virtual reality.

NEW YEAR HONOURS LIST

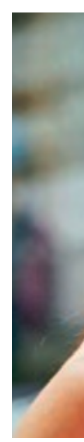
MEMBER AWARDED AN MBE

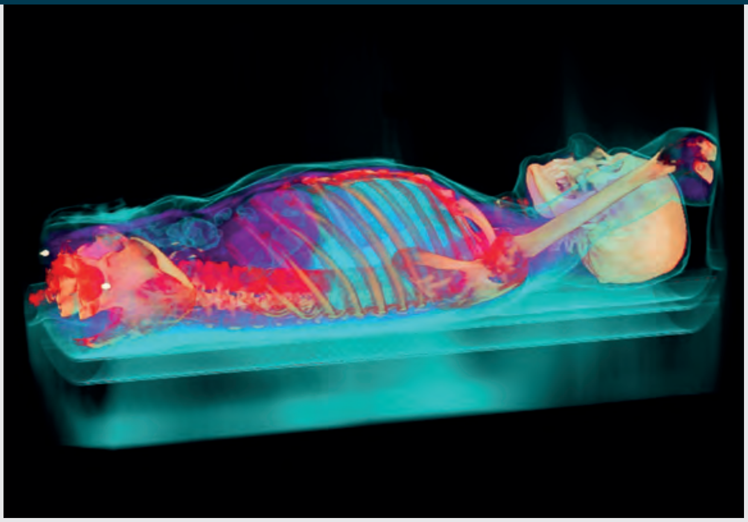
AN Honorary Fellow of IPEM has been awarded an MBE in the New Year Honours List.

Professor Heidi Probst, a leading researcher in radiotherapy for patients diagnosed with breast cancer, was made an MBE for services to radiography.

Professor Probst is a former Director of the Health Research Institute at Sheffield Hallam University, where her research is currently looking at ways to improve the accuracy and reproducibility of breast irradiation whilst ensuring the patient experience is as positive as possible.

She is the founder and chair of the Breast Radiotherapy Interest Group and is chief investigator for two radiotherapy breast cancer studies: the SuPPORT 4 All study, which designed a novel support bra for women to wear during breast irradiation, and the RESPIRE project, to develop a series of online patient resources to support patients undergoing breath hold techniques as part of their radiotherapy.





ARTIFICIAL INTELLIGENCE

NEW IPEM AI group

An artificial intelligence (AI) group has been launched by IPEM.

The AI Group is intended to run parallel to IPEM's Special Interest Groups (SIGs) in a similar way to the Environmental Sustainability Group.

By working in this way, the AI Group can ensure alignment and efficiency of output from IPEM, identifying areas of overlap and collaboration between SIG activities relating to AI.

The AI Group is now developing its workplan to:

- Connect with the SIGs to ensure full representation
- Connect with external bodies, such as the Royal College of Radiologists, trade association AXREM and the Society of Radiographers
- Carry out work to establish what IPEM members' needs and aspirations are regarding AI
- Decide on workstreams and develop plans to progress them
- Engage with IPEM members (through the AI and Machine Learning Community of Interest) to understand topics and issues members feel should be raised for consideration by the AI Group and to share the Group's activities.

If you have any questions or suggestions for the AI Group, please head to the AI and Machine Learning Community of Interest.

IMAGES: SHUTTERSTOCK/REX

Professor Probst said: "I was overwhelmed that someone took the time to nominate me for this award, and I am delighted to receive it and fly the flag for all therapeutic radiographers and healthcare professionals that work tirelessly to improve the delivery of radiotherapy and care for patients diagnosed with cancer."

Dr Anna Barnes, IPEM's President, said: "I'm delighted Heidi has received this award. Her research to support improving outcomes for patients is crucial and this is a fitting recognition of her work in this area."

ENGAGING WITH CHILDREN

IPEM Fellow awarded outreach prize

An IPEM Fellow has been awarded a prize for her work to help educate schoolchildren about medical physics.

Professor Carmel Moran, who is Chair of Translational Ultrasound at the Centre for Cardiovascular Science at the Queen's Medical Research Institute at the University of Edinburgh, has been awarded the IPEM Spiers' Prize for Outreach.

She won a ScotPEN Wellcome Engagement Award for a project entitled "Imaging Inside-Out", which was aimed at Scottish secondary school pupils to reveal how imaging and physics techniques are applied in clinical and preclinical (animal) scenarios to learn more about health and disease.

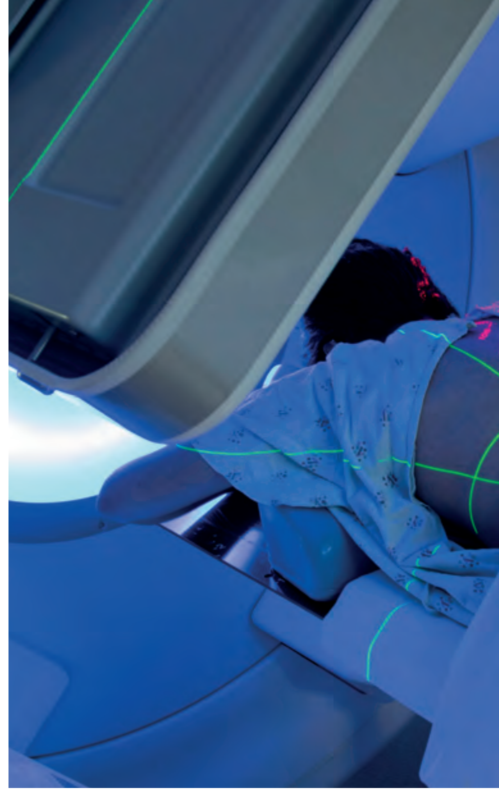
Professor Moran said: "I am delighted to win this IPEM Spiers outreach prize. The outreach team, which is composed of students and post-doctoral researchers from both the University of Edinburgh and Heriot Watt University, have really engaged and excelled in discussing imaging physics with young people in schools and Scout groups. This award is a tribute to their enthusiasm."

Dr Anna Barnes, IPEM's President, said: "Congratulations to Carmel and the team for their dedicated work to promote and educate schoolchildren about medical physics, a cornerstone of IPEM's charitable objectives."

POLICY UPDATE

Impact of visa changes

Sean Edmunds, the Institute's External Relations Manager, outlines recent key policy updates.



A letter was sent to the Home Secretary James Cleverly earlier this year expressing concerns about changes to the visa system and the potential impact on the UK science sector.

IPEM was one of several professional bodies and Royal Societies to sign the letter, organised by the Science Council, to Mr Cleverly, expressing concerns about the potential impact the changes could have on the science sector.

The letter, which called for an urgent meeting with the Home Secretary, expressed concerns the changes to visa policy could create barriers to the continued success of the science sector, particularly for early career scientists. It stated the new minimum income requirement of £38,700 is above the average starting salary in the UK for postdoctoral researchers, technicians and other vital scientific roles.

Investment in radiotherapy

IPEM also supported an updated manifesto calling for a modern world-class radiotherapy service in the UK.

AXREM, the UK trade association representing the interests of suppliers of diagnostic medical imaging, radiotherapy, healthcare IT and care equipment including patient monitoring, launched the updated manifesto at the House of Commons to help raise awareness and visibility of the issues surrounding radiotherapy.

The manifesto highlighted concerns around patient access to radiotherapy treatment, the age profile of the equipment and the need for significant investment in the service.

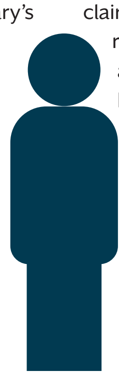
IPEM has a memorandum of understanding with AXREM to share knowledge and bring industry, the NHS and academia together to deliver benefits for the wider profession of medical physics and clinical engineering.

Nicky Whilde, Chair of IPEM's Radiotherapy Professional Standards Panel, who was at the launch of the manifesto, said: "We welcome the launch of AXREM's radiotherapy manifesto, which highlights how important joint working is between manufacturers, professional bodies, and the NHS to support the best possible treatment for patients having radiotherapy.

"The manifesto set out many objectives that IPEM has also been calling for, including centralised funding for replacement of large pieces of capital equipment in England."

Tim Farron MP, and Chair of the All-

INVESTMENT IN PEOPLE AND EQUIPMENT



Back in the autumn, IPEM criticised one Health Secretary's call to stop recruiting to EDI roles and shortly after gave a cautious welcome to his replacement.

A call by the then Health Secretary Steve Barclay for NHS leaders to stop recruiting to roles promoting diversity and equality was labelled a "distraction" by IPEM.

Mr Barclay was reported to have written to NHS leaders claiming such roles did not represent value for money and the money would be better spent on patient care.

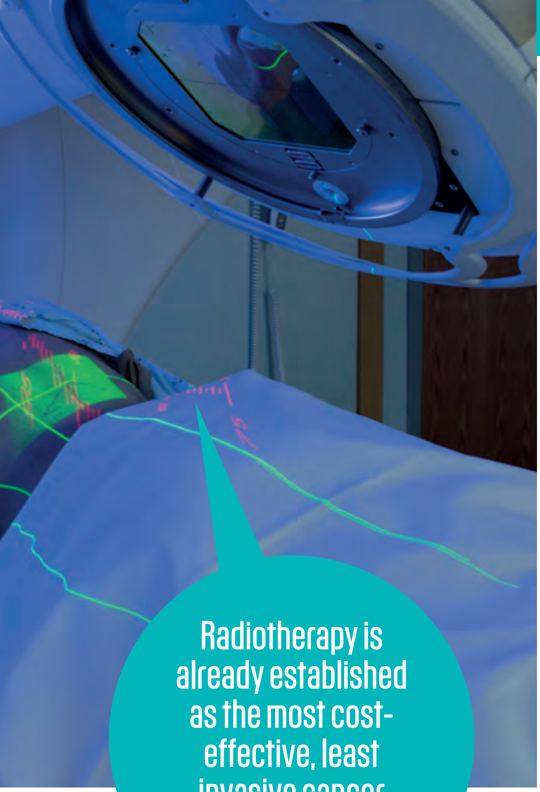
Dr Anna Barnes, IPEM's President, said a diverse science workforce was essential for science to better serve society and patients and labelled Mr Barclay's call a "distraction" from the real issues facing the NHS workforce.

A mere matter of weeks later, IPEM was giving a cautious welcome to new Health Secretary Victoria Atkins following a Cabinet reshuffle.

Dr Barnes said Ms Atkins needed to urgently address workforce shortages in healthcare science in general and in the medical physics and clinical engineering community in particular.

"Unless the government is prepared to tackle the lack of investment and inadequate numbers of training places in healthcare science, they will not make inroads into the backlogs, particularly in cancer diagnosis and treatment. We urgently need investment in people and equipment," said Dr Barnes.

IMAGES: ISTOCK/SHUTTERSTOCK



Radiotherapy is already established as the most cost-effective, least invasive cancer treatment available

"THE MANIFESTO SET OUT OBJECTIVES THAT IPEM HAS BEEN CALLING FOR

Party Parliamentary Group for Radiotherapy, said: "Radiotherapy is already established as the most cost-effective, least invasive cancer treatment available. The radiotherapy industry will be responsible for taking this technology further and faster – saving the NHS vital cancer funding, making treatment more patient-friendly, and improving the UK's shocking cancer survival rates. I endorse the AXREM manifesto for radiotherapy so that these aims are made reality."

Sexual safety in healthcare

IPEM also signed a charter to tackle unwanted, inappropriate and harmful sexual behaviour in the workplace.

NHS England's Sexual Safety in Healthcare Charter commits organisations who have signed it to a zero-tolerance approach to any unwanted, inappropriate and/or harmful sexual behaviours towards its workforce.

IPEM has now joined almost 170 other organisations, including royal colleges and other professional bodies, as well as scores of NHS trusts, to sign the charter.

The Institute is already a signatory to the Royal Academy of Engineering Diversity Concordat and the Science Council's updated diversity declaration. IPEM also has an Equality, Diversity and Inclusion policy and extensive EDI action plan that covers all areas of the organisation.

A MAN'S WORLD

STRIVING FOR EQUITY, DIVERSITY AND INCLUSION

Clinical Scientist **Virginia Marin Anaya** looks at under representation of women in STEM and the stories of inspiring women whose incredible work has gone unacknowledged.

As a Clinical Scientist in medical physics who works for the NHS, I spend a lot of time explaining to people what I do on a typical day. In my personal experience, most people are not aware of the important roles that Clinical Scientists play in the NHS, even though these roles are vital to ensure correct diagnosis, treatment and prevention of illnesses and contribute to the deployment of cutting-edge medical equipment and innovative techniques for patient benefit. Moreover, people in general seem surprised when I tell them that I am a physicist because I apparently look quite approachable and "normal". The stereotype – heavily influenced by TV and social media – that portrays scientists as nerdy and socially awkward white males who wear white coats and work alone in labs, is inaccurate and needs to be challenged. More people, particularly women, who value teamwork, collaboration and would like to make a difference, would probably pursue a career in STEM (science, technology, engineering and maths) if they knew how vast the roles really were. The aim of this article is to explore my initial experience of becoming a STEM Ambassador and to share lessons learned through my own reflections of that activity, highlighting the importance of including women and other under-represented groups in STEM.

STEM statistics

We live in particularly challenging times and now more than ever we need people with STEM skills to work towards shaping a positive future. Even though the government has stated that it is committed to ensuring the UK remains at the leading edge of science, technology, research and innovation, there is an increasing shortage of people with STEM skills. Moreover, according to recent UK statistics, the percentage of female graduates undertaking STEM degrees is still just 27%. This figure decreases slightly when translated into careers, with women making up just 26% of the STEM workforce. From students to graduates and within the workforce, the fields of computer science, engineering and technology show the largest gender gap. Women make up only 12% of the UK's engineering workforce. Computer science is a fast-growing field, however, according to STEM statistics, in England in 2023 only 15% of A level computer science students were female. This is a worrying statistic for a field that is supposed to transform society, but the workforce does not resemble the society in which we live.

According to stemwomen.com, in the UK there has been an increase in the number of female and non-binary STEM graduates experiencing imposter syndrome, which refers to feelings of inadequacy or constant self-doubt despite evident success. Contributory factors for this include the rapidly evolving landscape in science and technology, the impact of the COVID pandemic, unequal share of housework and caring responsibilities, social media, and the under-representation of these groups in the STEM workforce, which makes them feel out of place and lack a sense of belonging. Women are also under-represented in STEM leadership, raising concerns about equity, diversity and inclusion in STEM, and lack of role models that might be driven by historic and institutionalised power imbalances and discrimination.

STEM skills in the NHS

The NHS is already facing unprecedented demands due to backlogs and staff shortages. The recent official IPEM statement calls for urgent action to address the Clinical Scientists, technologists and engineers recruitment and staff retention crisis in the UK. It is feared that without intervention the problem will worsen, raising concerns about the future of the medical physics and clinical engineering workforce to meet current demands in the NHS and potentially compromising patient care and safety. The *NHS Long Term Workforce Plan* has introduced apprenticeship training posts that will allow more people to pursue a career in STEM. However, there are still concerns that these posts are not going to be sufficient to cover current needs.

Moreover, across the NHS women and ethnic minority staff are under-represented in senior leadership positions. For example, only one in four Chief Financial Officers across the NHS are

> **"WOMEN AND ETHNIC MINORITY STAFF ARE UNDER-REPRESENTED IN SENIOR LEADERSHIP**

STEM STORIES: WHAT PUPILS THINK

Comments from secondary school pupils shared during a STEM Q&A session at a school assembly.

- **STEM subjects are perceived as challenging, hard, or boring.** Pupils would avoid them if they could because "they just lower your grades". Pupils choose to study certain subjects if they like the teachers and feel like they belong. "I don't want to feel like the odd one out." "I don't want to be the only girl in the class. It makes me feel uncomfortable." "I chose to study history because I like the teacher and I enjoy it."
- **There are differences between boys' and girls' interest and aspiration regarding career choice.** Girls prefer careers where they can easily see themselves making a difference and aspire toward careers in teaching, psychology, law, nursing, or medicine. Boys feel more drawn to career choices that would be fun and offer financial stability. In general, boys aspire towards careers in computer science, business, banking and finance, which are perceived as lucrative sectors.
- **Pupils feel under pressure.** There is a lot of focus on achieving top grades, which takes away the enjoyment of learning. They like teachers or STEM Ambassadors who can provide stimulating learning environments which lead to critical thinking."I like maths teachers that motivate you and provide lots of examples."
- **Pupils in general feel an increase in stress, anxiety, and lack of confidence due to the legacy of COVID and the impact it has had on their learning.** They appreciate the benefit from having role models in STEM whether they are teachers or STEM Ambassadors to boost their confidence, promoting an "I can" attitude for girls and other under-represented groups in STEM. "I had a tough time during COVID lockdown. I was getting stuck in maths and no one at home could help me."
- **Pupils think that the government is not doing enough to support children and teenagers in state schools.** They particularly worry about the cost-of-living crisis. Urgent action is needed to reduce the gap between the rich and the poor to build a more equitable society. They feel that pupils that go to private schools have a better chance of scoring top marks, attending their university of choice and transitioning into successful careers, including STEM careers, without having to worry about tuition fees.
- **Scientists are stereotyped as "white, eccentric, and anti-social males with odd-looking hair, wearing lab coats and working alone in labs."** Engineers, however, have a complete lack of stereotypes. Most pupils do not know what engineers do or think that "they just build bridges".
- **Computer scientists are stereotyped as "males in a hoodies that code all night in basements or dark rooms."** They appear to have the latest computer and can hack and gain unauthorised access to secure networks.

These stories illustrate the key impacts that stereotypes have on young people.

❶ Right: Marie Curie (1867–1934) was a Polish-French physicist and chemist famous for her pioneering research on radioactivity.

women. Ethnic minority staff make up only 11% of positions at senior managerial level. According to NHS England, in 2022 women got paid 14.7% less per hour on average than men. Women outnumber men in lower-tier roles, whereas men predominate in senior positions across the NHS, showing that more work needs to be done to achieve equity, diversity and inclusion at all levels of the NHS. This may be preventing some STEM graduates from applying for Clinical Scientist or engineering jobs in the NHS, which are critical to shaping the future of a scientifically and digitally enhanced NHS. Under-represented groups in STEM-related subjects value a diverse and inclusive workplace offering career progression and an environment where they can thrive and have a sense of belonging and community. Equity, diversity, and inclusion are now more important than ever, creating a fairer workplace, positive culture and reducing unconscious bias. This is vital for the future of the NHS and improving the services we provide to patients.

Becoming a STEM Ambassador

The STEM Ambassadors programme is funded by UK Research and Innovation, managed centrally by STEM Learning and delivered locally by STEM Ambassador Hubs. STEM Ambassadors are volunteers, representing a wide range of STEM careers across the UK. They offer their enthusiasm, energy and experiences to encourage and inspire young people to achieve more, develop a love of learning, make progress in STEM subjects, and promote STEM careers. STEM Ambassadors Hubs have been established to ensure schools and community groups can access these Ambassadors to inspire the next generation and champion the values of STEM careers. Part of being a STEM Ambassador is access to the STEM community and engagement with fellow members, sharing experiences and ideas, and accessing resources from the National STEM Learning Network.

I decided to become a STEM Ambassador because I want to make a difference by breaking stereotypes, inspiring the young generation to pursue a STEM career, and particularly informing them about career paths into medical physics and clinical engineering in the NHS. I am passionate about medical physics, and as a STEM Ambassador I share that passion with young people.

> **"WOMEN OUTNUMBER MEN IN LOWER-TIER ROLES, BUT MEN PREDOMINATE IN SENIOR NHS POSITIONS**

As a STEM Ambassador, I organised various activities through the London STEM Ambassador Hub in comprehensive schools in the heart of Camden and within walking distance of UCLH where I work. I found the IPEM outreach posters, leaflets, and other resources extremely helpful for the delivery of these activities. For example, during school assembly at a comprehensive school, I delivered an oral presentation on the roles of Clinical Scientists and engineers in the NHS and explained different routes that can lead to UK registration as a Clinical Scientist with the Health and Care Professions Council. The presentation was followed by a forum where open discussion was encouraged to determine what pupils thought about STEM subjects and how they perceived STEM people.

It is rewarding to reflect upon my STEM activity. See the box for some of the stories shared by secondary school pupils:

Although some progress has been made, there is still work to be done to challenge stereotypes. It is clear that scientists do have an image problem. These stereotypes and the lack of female and other minorities' role models in STEM may have a negative impact on career aspirations, contributing to the gender imbalance in STEM university degrees and consequently STEM careers. These inaccurate stereotypes may lead to children and teenagers believing that STEM is only for white, heterosexual men from privileged backgrounds.

> "ALTHOUGH PROGRESS HAS BEEN MADE, THERE IS STILL WORK TO BE DONE TO CHALLENGE STEREOTYPES

Awareness campaign

To challenge stereotypes, inaccurate perceptions and gender biases, The Spanish Association of Women in Research and Technology, with the support of the European Parliament, launched in 2021 the campaign "No More Matildas". It is named after Matilda Joslyn Gage – an American activist who fought for women's rights to vote in the US, and the first person to denounce the tendency to deny women the credit and acknowledgement they deserve for their STEM findings and achievements. The findings are ignored, overlooked, forgotten, or attributed to their male colleagues, partners, or husbands. This phenomenon known as "the Matilda Effect" illustrates a legacy of discrimination and highlights the injustice and unfairness of systematically ignoring the STEM findings of women throughout history. The Matilda Effect has prevented STEM women from being featured in textbooks to inspire girls who may think that STEM-related subjects are only for men.

The Nobel Prize is the most prestigious honour in the scientific community. However, the number of women scientists among Nobel Laureates is extremely low. Nobel Prize winners in STEM are mainly white and male. Among the 688 Nobel laurates in Chemistry, Economics, Physics and Medicine, there are only 20 women.

Marie Curie is one of the most famous scientists in history. However, she was almost excluded from winning the 1903 Nobel Prize in Physics for the discovery of radioactivity. It was her husband, Pierre, who forced the committee to add Marie to the nomination threatening to refuse the Prize otherwise. Without Pierre acting as her advocate there is little doubt that Marie would have become invisible. Although Marie became the first woman to win a Nobel Prize, she was not treated as an equal. Marie and Pierre received a single sum of the award to share, while Henri Becquerel, received the entire share of his award. In addition, she was excluded from taking part in the speeches. In 1911 she won the Nobel Prize in Chemistry for the discovery of Polonium and Radium, becoming the first person to win a Nobel Prize twice, and the only person to win a Nobel Prize in two different fields. Despite her talent and accomplishments, she was not allowed to become a member of the French Academy of Sciences because she was female.

thesis. For this discovery, the 1974 Nobel Prize in Physics was awarded to Sir Martin Ryle and her PhD supervisor Antony Hewish. She was not one of the recipients.

● **Chien-Shiung Wu** was a Chinese American physicist who proved that the principle of parity conservation does not apply during beta decay. For this discovery, her male colleagues Tsung-Dao Lee and Chen-Ning Yang won the 1957 Nobel Prize in Physics.

● **Katherine Johnson** was an African American mathematician. She worked for NASA, where she and other women worked as "human computers," making space exploration possible by calculating the trajectories of space missions, such as Apollo 11.

● **Grace Murray Hopper** was an American Computer Scientist who made significant contributions to computer programming and software development. She was responsible for the development of COBOL (Common Business Oriented Language) computer programming language.

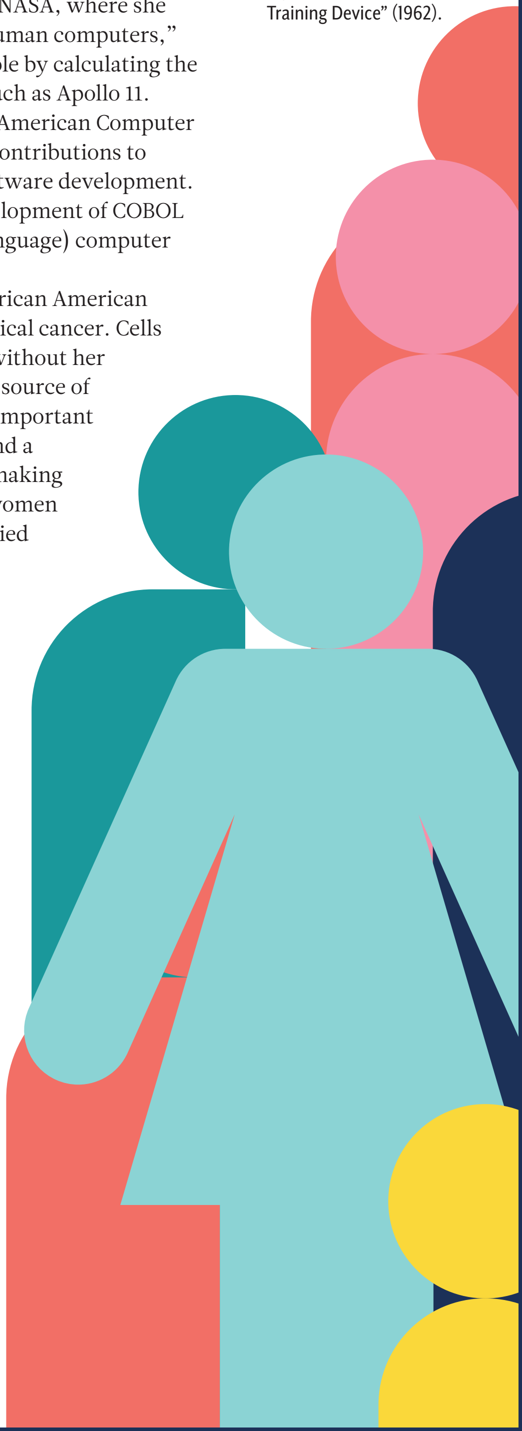
● **Henrietta Lacks** was a poor African American tobacco farmer who died of cervical cancer. Cells were removed from her uterus without her informed consent. These are the source of HeLa cell line – one of the most important cell lines in scientific research and a multi-million-dollar industry, making her one of the most influential women in science and innovation. She died without acknowledgment or financial compensation.

● **Margarita Salas Falgueras** was a Spanish biochemist and a pioneer in DNA testing at a time when Spanish women were forbidden from working unless they obtained consent from their husbands. Despite experiencing prejudice and gender discrimination, but with her husband's permission, she invented a method, known as "multiple displacement amplification", to replicate trace amounts of DNA into quantities large enough for full genomic testing. Her invention, registered with the European Patent Office, is used widely in oncology, biotechnology, forensics, and archaeology, bringing millions of euros for reinvestment in Spanish science.

● **Alice Augusta Ball** was an African American chemist.

❷ **Left:** Lise Meitner (1878–1968) was an Austrian-Swedish physicist (1906).

❸ **Right:** Katherine Johnson (1918–2020) NASA research mathematician, at her desk at NASA Langley Research Center with a globe, or "Celestial Training Device" (1962).



Sidelined STEM women

The impact of the Matilda Effect goes beyond the Nobel Prize and can still be seen today. There are many extraordinary women who have helped advance STEM, but their contributions to STEM have not been appropriately acknowledged or recognised. Many of their stories have been taken for granted, overlooked, or forgotten. It is crucial to recognise the achievements of women in STEM to ensure that their legacies are not lost to history. Here are only a few examples of sadly many Matilda stories:

● **Lise Meitner** was an Austrian-Swedish physicist who contributed to the discovery of nuclear fission. The 1944 Nobel Prize in Chemistry for this discovery was awarded exclusively to her male fellow collaborator Otto Hahn.

● **Marietta Blau** was an Austrian physicist who developed photographic nuclear emulsions contributing to the field of particle physics. The 1950 Nobel Prize in Physics for the development of the photographic emulsion method and the discovery of the pion particle using Marietta Blau's method was awarded exclusively to Cecil Powell.

● **Rosalind Franklin** was a British chemist and X-ray crystallographer. Her work on X-ray diffraction made imaging of DNA possible, revealing the DNA double helix. Her work was critical to the understanding of the molecular structure of DNA. However, her contribution to the discovery of the structure of DNA was unrecognised during her lifetime. Francis Crick, James Watson, and Maurice Wilkins shared the 1962 Nobel Prize in Medicine for this discovery.

● **Jocelyn Bell Burnell** is an astrophysicist from Northern Ireland who first discovered radio pulsars in her doctoral

IMAGES: ISTOCK/ALAMY

4 Left: Alice Augusta Ball (1892–1916) was an American chemist who developed the "Ball Method" treatment for leprosy.

She was the first woman and the first African American to achieve a master's degree from and teach chemistry at the University of Hawaii. She discovered a method to treat leprosy. Unfortunately, she died very young. Her findings were taken by a male scientist who failed to acknowledge Ball's contribution, presenting them as his own.

- **Mileva Maric** was a Serbian physicist and mathematician and the first wife of Albert Einstein. It is said that she may have contributed to her husband's early work. However, she may not have been added as an author to some early publications because papers co-authored with a woman would have carried less scientific weight at the time. We may never know the truth. Perhaps the fact that after their divorce Albert gave Mileva all the share of the award he received for winning the Nobel Prize was some kind of acknowledgment or recognition to her. Nevertheless, she was one of the first women in Europe to study physics and mathematics, breaking barriers and paving the way for future generations of women in STEM.

Summary

The contribution of STEM subjects to the economy should not be underestimated. STEM careers contribute to driving innovation, social well-being, inclusive growth, and sustainable development. However, for years, women, ethnic minorities, LGBT+, disabled people and people from disadvantaged backgrounds have been under-represented in STEM university courses and careers. There is still work to be done to encourage these groups to study STEM subjects and transition into STEM careers to ensure an inclusive and diverse workforce. STEM Ambassadors play a crucial role in helping make this happen by challenging perceptions, promoting female and other minorities' engagement in STEM, supporting schools with limited resources, bringing STEM subjects to life with a variety of activities and creating a supportive and inclusive culture where diverse thinking and experiences are valued.

The consequences of the Matilda Effect can still be seen today. The "No More Matildas" campaign aims to provide female role models to encourage STEM interest among girls, promoting gender equality in STEM and raising awareness of the global issue of unequal opportunities of women in STEM. The lack of female role models may have a negative impact on girls' career aspirations, contributing to their under-representation in STEM degrees and careers.

> **"A DIVERSE AND INCLUSIVE NHS WORKFORCE AT ALL LEVELS IS KEY TO SUCCESS**

If you have been inspired by reading this article, here are some actions that you can take:

- Become a STEM Ambassador, inspiring and empowering the next generation to unlock their full potential. The process is easy. You just have to register online at stem.org.uk, apply for a free enhanced disclosure check, complete the online induction, connect with your local STEM Ambassador Hub, and start volunteering. Reach out, promote healthcare science, and raise awareness of the role healthcare scientists play in the NHS. Collaborate with other STEM Ambassadors to create a greater impact.
- Support and raise awareness of the No More Matildas campaign, embracing equity, diversity, and inclusion values. Challenge stereotypes, change perceptions and share the No More Matildas YouTube video with friends, family, and colleagues.
- Celebrate Ada Lovelace Day, which is named after one Matilda: Ada Lovelace – mathematician and the world's first computer programmer. It is an international day held every year on the second Tuesday of October to celebrate and raise awareness of the contributions of women to STEM.
- Raise awareness of The Malala Fund – a charity co-founded by Malala Yousafzai and devoted to bringing equal education opportunities to girls and women around the world, helping decrease the gender gap. A total of 130 million girls are denied the human right to education in 2023. According to the United Nations, it will take 286 years for the world to achieve gender equality.
- Encourage more women, ethnic minorities, and other under-represented groups to apply for leadership roles. This, in turn, can have a ripple effect and encourage under-represented groups to apply for roles in STEM. Having a diverse and inclusive NHS workforce at all levels of the organisation is key to success and essential for delivering high quality care, embedding cultural change throughout the NHS, and creating a legacy for the future.

Virginia Marin Anaya *is a Clinical Scientist at University College London Hospitals NHS Foundation Trust. She would like to thank the pupils and teachers at Maria Fidelis Comprehensive School in London for their input and enthusiasm.*

Member profile: Dr Kate Bryant

I work as a Consultant Clinical Scientist, Head of Non-ionising Radiation in the Medical Physics and Clinical Engineering Department at Cardiff and Vale University Health Board. I am also an Honorary Associate Professor in the Faculty of Medicine, Health and Life Science at Swansea University.

Tell us about a typical work day.
A typical day is a mix of performing patient scans at vascular clinics, laser safety audits, or lecturing at Cardiff University, alongside service and workforce management.

Which elements of your job do you like the most?
My favourite aspect of my role is working directly with patients within a multidisciplinary clinical team and directly contributing to patient care.

What are the biggest challenges you see – either for yourself or the sector?
The use of ultrasound and lasers is rapidly expanding throughout healthcare, and it is important that our non-ionising medical physics workforce can grow with demands.

If you could change one thing about the profession or your area of specialty, what would it be and why?
I would make vascular ultrasound STP training available within medical physics. The removal of Doppler ultrasound from the medical physics Clinical Scientist Training Programme has posed significant challenges in training and maintaining the medical physics workforce in Doppler ultrasound.

What skillsets do you think are required to be successful in your role, and is there a particular career path or training option you would recommend?
I would recommend undertaking a PhD or part -time PhD, alongside or prior to undertaking HSS equivalence, as an alternative option to HSST. It is important we maintain a workforce with a strong research and academic background, in addition to clinical skills.

What accomplishment have you been most proud of in your career?
Completing my PhD part-time in three years, alongside my Part II IPEM higher training and working full-time in my Band 7 Clinical Scientist role was an achievement at the start of my career.

More recently, leading my team and service through the pandemic and receiving the IPEM President's Gold Medal Award for Exceptional Service during the COVID 19 pandemic.

Why did you join IPEM?
I joined IPEM as an Associate Member when I first started my IPEM Grade A training.

I was supported through my training, becoming a Member of IPEM on completion of my Part II higher training. I was a member of the IPEM Physiological Measurement Special Interest Group (2013-2016), and I contributed to the STP guidance notes for STP trainees, published by IPEM. In 2013, I was nominated as an IPEM Member of the Academy for Healthcare Science (AHCS) Medical Physics Professional Group and involved with setting the training standards for the STP equivalence route. I'm now an assessor for AHCS STP equivalence, and assessor for the Association of Clinical Scientists Route 2 Clinical Scientist equivalence applications.

I was a Member of the Royal College of Radiology first FRCR Examination Committee (2013-2019), setting the syllabus, examination and pass standards for Part 1 Radiology SpRs. I was awarded Honorary Membership of the Royal College of Radiology for my contribution.

I've recently applied for IPEM Fellowship and would encourage anyone thinking of applying to do so. I've also been appointed as Joint IPEM Vice President for Wales, and I'm looking forward to the opportunities and challenges this role may bring.

IMAGES: ISTOCK/SHUTTERSTOCK

RADIATION PROTECTION

Considerations for 3D intraoperative imaging

Dan Shaw and **Vanessa Kilhams** of University Hospitals Plymouth NHS Trust look at the evaluation of a 3D cone beam fluoroscopy system.

Intraoperative imaging is a critical component of many modern surgeries, particularly those using minimally invasive techniques. Minimally invasive surgery can utilise intraoperative imaging to spare muscles and healthy tissues while improving the accuracy of the procedure. Image guidance using mobile image intensifier (II) fluoroscopy has long been established to provide the image guidance. Whilst it was possible to carry out 3D cone beam imaging with II technology, the technical limitations such as distortion (s-type and pincushion) degrading the reconstructed images were a barrier to the widespread adoption of this technology. As II fluoroscopy was used for planar imaging, there was often a requirement for pre- and post-conventional CT imaging for planning the surgery and to evaluate its effectiveness respectively. Where post-surgical CT imaging was performed and issues were highlighted, this could result in the patient requiring further corrective surgery.

Flat panel detectors (FPDs) resulting in relatively distortion-free images allow 3D reconstructions of cone beam images with improved image quality compared to II technology. This, along with other improvements, such as X-ray tube and generator technology, means that the resulting 3D reconstructions can be of suitable diagnostic quality to potentially replace conventional CT imaging for planning and evaluating surgeries.

The 3D imaging capability has the potential to be integrated with the surgical process further still, such as with surgery robotics to improve workflow and patient outcomes.

Whilst this transition in technology has largely completed for fixed units, mobile units are yet to be dominated by this technology. However, the introduction of this technology is happening at pace with several units now on the market, including mobile CT units mimicking traditional CT systems, cone beam fluoroscopy units and O-arms (a hybrid technology of the other two technologies).

Introducing 3D imaging systems to theatres potentially has implications for patient and staff dose and requirements for radiation protection. In addition, UK ionising radiations regulations set out key requirements, such as a suitable radiation risk assessment prior to commencing work with one of these units which must consider dose limits and constraints (including instantaneous dose rates).

IMAGES: SCIENCE PHOTO LIBRARY

Should the 3D intraoperative imaging be used to supplement or replace conventional CT imaging, comparisons of effective dose are required to aid with the justification process. Estimates of effective dose for fluoroscopic systems will always contain significant errors due to the nature of the automatic dose rate control varying exposure parameters but it is possible to make representative models of different scenarios utilising Monte Carlo dose modelling software.

We were fortunate to be able to evaluate one such 3D cone beam fluoroscopy system. Whilst the specifications for other units on the market may differ, we believe that where the underlying radiation physics principles are sufficiently similar that our results can be carefully extrapolated to these alternatives to aid in forming the basis for the prior risk assessment (keeping in mind that this may need to be refined as further data becomes apparent).

The specific aims of this work are:

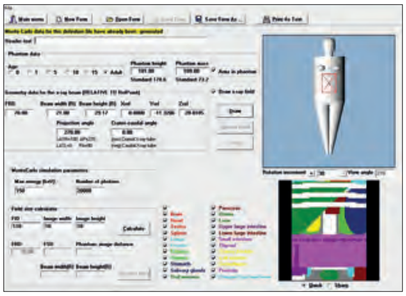
- to evaluate the patient dose to inform the case of whether this imaging is optimal for patients when compared to conventional CT imaging
- to establish the environmental radiation doses.

Methods

Estimates of patient effective dose

The unit evaluated had three image quality modes associated with 3D imaging and each was evaluated. Information about dose area

❶ Example of Monte Carlo model



❷ Example of Monte Carlo model effective dose estimate

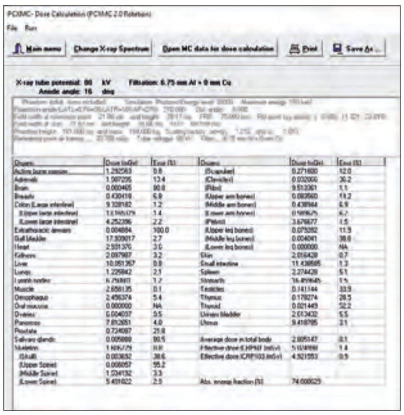


Figure ❸ Experimental setup

product (DAP) was obtained by imaging a Kyoto phantom and recording the DAP (the DAP meter accuracy having been verified against a DAP meter with a traceable calibration) and imaging the lumbar spine region. The Kyoto phantom was positioned on an operating theatre table. To obtain an indication of the maximum DAP output of the system, a lead apron was placed over the phantom (large patient) with the additional attenuation resulting in the automatic dose rate control requiring maximum tube output.

Monte Carlo dose modelling was carried out utilising the PCXMC20 Rotation software ❶ ❷ assuming that the DAP was shared equally between each pulse. Simulations were carried out at 80kVp and 120kVp. The values at 80kVp are what may be considered "typical" for an average sized patient (approximately 75kg). Other factors required for the model were taken from measurement or the manufacturers specification.

Environmental dose rates

Using the same setup described above, dose and dose rate measurements were made using a Raysafe X2 survey chamber with a calibration traceable to primary standards ❸.

Measurements were taken around the unit to identify the area of highest dose. Measurements were then collected at 3 meters from the isocentre (assuming a 6m by 6m operating theatre) to identify the dose and dose rates that can be encountered for the three different image quality modes available.

Results and Discussion

Estimates of patient effective dose

The results of Monte Carlo dose modelling of effective dose are given in ❹.

These values are comparable to the HPA-CRCE-028 conversion factor of approximately 0.20 for planar lumbar spine investigations. It is anticipated that the medium mode is likely to be used clinically. It was noted that for the unit evaluated that whilst the change from high to medium reduces the X-ray unit output per pulse and therefore increasing the quantum noise, the change from medium to low approximately halves the number of frames obtained and therefore the reconstruction of the image is likely to be affected differently. Optimisation of when to utilise the different modes would therefore be required.

In terms of radiation dose, HPA-CRCE-028 indicates that the total effective dose from orthogonal planar views of the lumbar spine is approximately 0.6mSv. This is comparable to 3D imaging using this system in medium mode for an average sized patient.

3D imaging utilising this unit is viewed as potentially replacing up to two conventional CT imaging procedures. There is not currently a national diagnostic reference level published for CT imaging of the lumbar spine. HPA-CRCE-012 presents an effective dose for this examination of 6.9mSv. Local audit data (and using the Shrimpton et al conversion factor for abdomen and pelvis of 0.02mSv/mGy.cm) indicates that this figure remains relevant.

Environmental dose rates

Based on the measurements obtained, the values in ❹ were calculated based on a 30 second (from equipment manual and confirmed from measurements) spin duration. As the unit has to reconstruct images and reset between 3D acquisitions it was not possible to perform more than one 3D exposure per minute with this system.

It was found that at the position of peak scatter, the dose was between 2.48 and 2.94 uGy (Gy cm^2)$^{-1}$ @ 1m for a single 30 second rotation. This compares to published values of 5 uGy (Gy cm^2)$^{-1}$ @ 1m for planar exposures. This lower value is likely due to the rotational nature of the acquisition

"

OUR EXPERIENCES INDICATE THAT 3D INTRAOPERATIVE IMAGING IS LIKELY TO HAVE A POSITIVE PATIENT BENEFIT

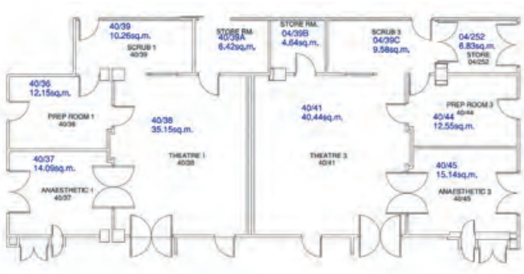
❹ Modelled patient effective dose

Mode	DAP ($Gycm^2$)	kVP	Effective dose (mSv)	E_{103}/DAP conversion factor
Low	1.91	80	0.3	0.16
Medium	3.77	80	0.6	0.16
High	13.40	80	2.1	0.16
High	21.55	120	4.9	0.23

❺ Radiation dose measured at 3 metres from isocentre at point of highest dose rate

Image quality setting	Phantom size	Max Instantaneous dose rate (μGy/hr	Total dose (μGy)	Dose rate averaged over 1 minute (μGy/hr)
Low	Average	334	0.62	37
Medium	Average	581	1.23	74
High	Average	1780	3.71	222
Low	Large	933	2.60	156
Medium	Large	1337	4.65	279
High	Large	2222	7.62	457

❻ Example of "typical" operating theatre layout



❼ Example of low-level air ventilation (lower right hand side)

resulting in the peak instantaneous dose rate changing position with the tube and detector orientation. A realistic approach for 3D imaging when estimating dose at the boundary would be to assume 3 uGy $(Gy\ cm^2)^{-1}$ @ 1m.

Assuming 3m from isocentre to an unshielded boundary with 100% occupancy, the member of the public (0.3mSv) dose constraint would be exceeded assuming standard sized patient and medium dose rate following approximately 243 3D acquisitions (less than one spin per working day). It should be noted that this does not account for the conventional 2D fluoroscopy imaging component. Whilst each controlled area requires its own bespoke calculations and radiation risk assessment the possible annual radiation workloads indicates that consideration of dedicated shielded facilities for these units may be required. This is further reinforced by the instantaneous dose rates and the dose rate averaged over a minute when compared with the accompanying code of practice and the guidance to the Ionising Radiations Regulations 2017. When shielding a theatre, thought would also need to be given to the practicalities of demarcation and access control for the controlled area given there are typically often several entrances (❻ indicates a layout that may be encountered).

Conclusions

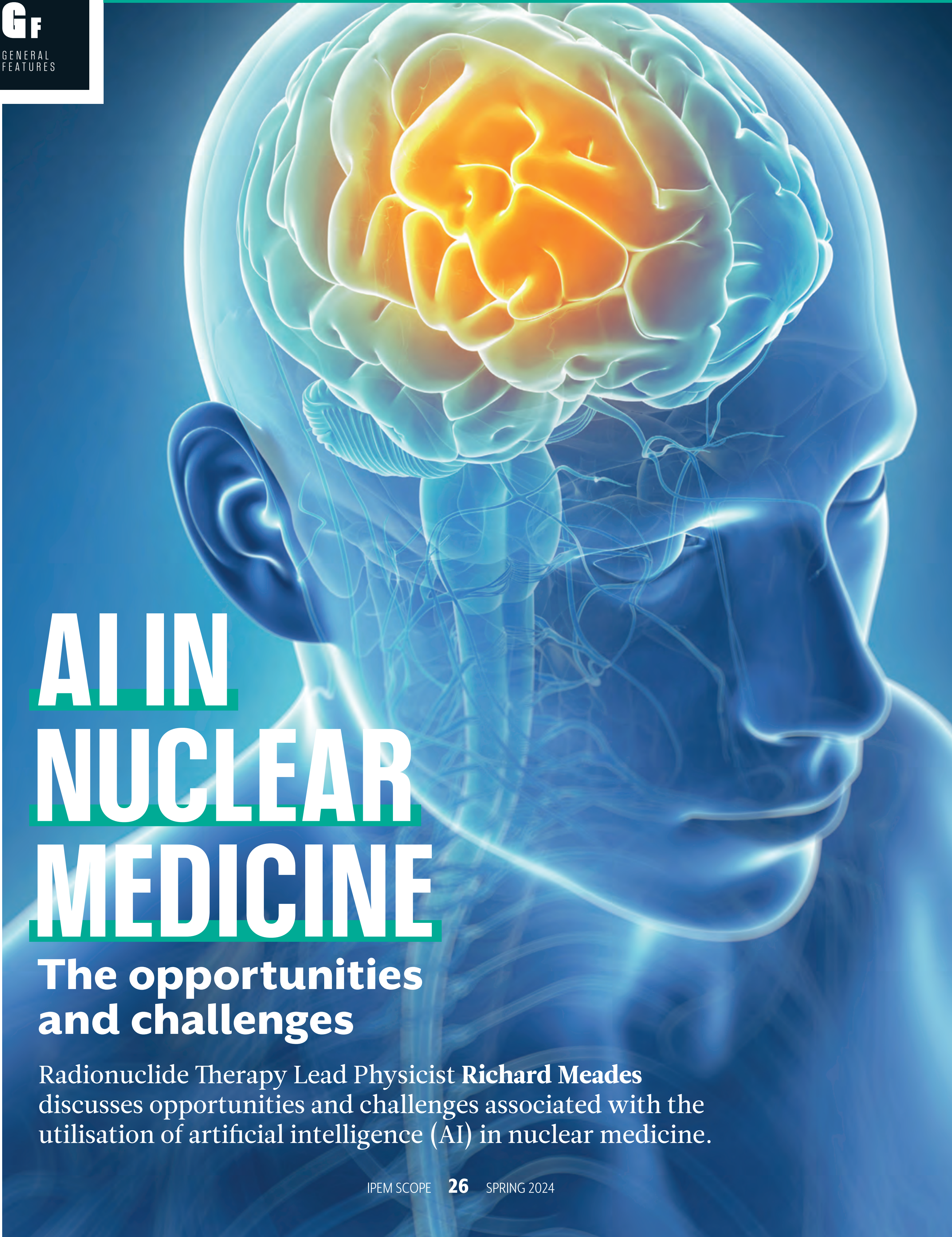
Modelling of effective dose indicates that 3D intraoperative imaging systems such as the one evaluated can result in 3D images at lower effective dose when compared with a conventional CT scan of the equivalent anatomy. The additional benefits to the patient and workflow can be summarised as:

- Pre-surgery planning CT scan can be performed in the operating theatre.
- Reduced gap between imaging and surgery.
- Reduced dependence on conventional CT resource and its competing demands.
- 3D imaging and treatment plans can be integrated with the robotics used for performing the surgeries potentially improving the outcomes of the surgery.
- Post-surgery imaging can be gained immediately following surgery in the operating theatre.
- Issues can potentially be corrected immediately improving patient outcomes and experience.

Implementation of this practice to the theatre environment may require that engineering controls (such as use of radiation shielding and good access control) may be required. This is supported by the measurements obtained with the system used for this evaluation. Consideration will also need to be given for protection of individuals essential to remain in the room during an exposure.

Whilst our measurements and experiences indicate that 3D intraoperative imaging is likely to have a positive patient benefit, it does also indicate that thorough review of the radiation risk assessment is required to ensure that the change of practice (either on a trial basis or permanently) is introduced safely and appropriate engineering controls and systems of work are in place.

__Dan Shaw__ is a Consultant Clinical Scientist and __Vanessa Kilhams__ is a Principal Clinical Scientist. Both are based at University Hospitals Plymouth NHS Trust.



AI IN NUCLEAR MEDICINE

The opportunities and challenges

Radionuclide Therapy Lead Physicist **Richard Meades** discusses opportunities and challenges associated with the utilisation of artificial intelligence (AI) in nuclear medicine.

AI is one of the most talked about topics in healthcare today, and for good reason – AI has the potential to transform how we provide care and improve patient outcomes. It is impacting all branches of medicine, with clinical adoption in radiotherapy already a reality. While its emerging role in nuclear medicine is in its infancy, its integration in this field holds immense potential. With its utilisation of radiopharmaceuticals for imaging and therapy at the molecular level, it has long been at the forefront of medical advancements. The integration of AI in nuclear medicine offers a promising opportunity to further enhance its accuracy, efficiency and personalised patient care.

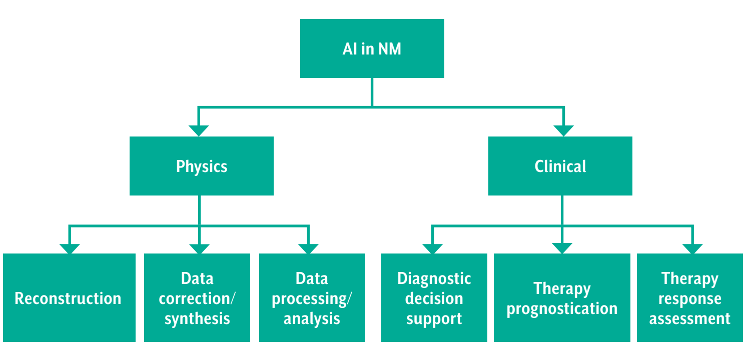
In this, the second in a new *Scope* series investigating AI in medical physics and clinical engineering (MPCE), we will explore the current state, opportunities and challenges associated with the utilisation of AI in nuclear medicine by highlighting current and potential applications and examining the obstacles that need to be overcome. By understanding the landscape and exploring future directions, we can attempt to grasp the transformative impact that AI can have on nuclear medicine and ultimately improve patient outcomes.

" THE INTEGRATION OF AI IN NUCLEAR MEDICINE OFFERS A PROMISING OPPORTUNITY TO FURTHER ENHANCE ACCURACY, EFFICIENCY, AND PERSONALISED PATIENT CARE

Applications

Whilst not yet ready for routine clinical use in most settings, initial research into the application of AI, specifically in nuclear medicine, shows promise in both the medical physics and clinical settings. Within the landscape of nuclear medicine physics, we are starting to see its use throughout the imaging pathway, from image reconstruction and data corrections through to image processing and finally analysis. Clinical applications include clinical decision support for diagnosis, prognostication and stratification for therapy response assessment across numerous specialisms, including neurology, cardiology and oncology. As we go on to discuss some of these applications in more detail, it is worth bearing in mind that, whilst we will not explore them here, there are numerous other potential applications and areas of research of AI that are not specific to nuclear medicine but relate to other stages in the patient pathway that are common to all imaging modalities and healthcare settings e.g. patient, selection, scheduling and preparation and automated report generation.

Figure ❶: Artificial intelligence in nuclear medicine



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Physics meets AI

Starting at the beginning of the imaging pathway, AI in the form of deep learning (DL) has introduced a paradigm shift away from pure physics modelling in image reconstruction by offering the possibility of a purely data-driven approach. Raw sinograms are mapped to an estimate of the desired image with the mappings learned from training data with ground truth images (e.g. DeepPET, DPIR-NET). The algorithms require a large amount of training data and, to date, have only been practical to apply to 2D image reconstructions but are fast to run once trained. As revolutionary as this sounds, in reality it is a refinement of this approach that is demonstrating greater potential. A blended approach combining data-driven methods with physics modelling by embedding AI in the image reconstruction process leads to faster convergence and more accurate final image estimation whilst requiring less training data and being practical for 3D image reconstruction (BCD-Net, MAPEM-Net, FBSEM-Net). These algorithms all aspire to achieve image quality improvements for the same scanning time and administered activity, or equivalent image quality for less radiation dose, or faster scanning times (or a combination). Work to date demonstrates the limitation that these algorithms can generalise poorly beyond the types of images upon which they are trained. A great deal of work is still needed to evaluate their robustness in larger patient populations and compare their performance to DL-based post-processing image improvements.

DL-based resolution improvement and de-noising

The main focus in this area of application is DL-based resolution improvement and de-noising techniques in PET and SPECT imaging. Resolution improvement is achieved using a large dataset of high-resolution images paired with their corresponding low-resolution counterparts. The latter is typically obtained by applying a down sampling process or simulating lower quality imaging conditions. A deep convolutional neural network (CNN) is then trained using these paired images to learn the underlying patterns and relationships between the images. It is then able to act as a mapping function that takes previously unseen low-resolution images as input and outputs enhanced, higher-resolution images. Similarly, in denoising, a dataset of noisy images paired with their clean versions is collected and used to train a DL algorithm so that it learns to identify the statistical properties of the noise. Examples include SubtlePET, which is a commercially available de-noising software algorithm that has been cleared by the FDA to provide image quality improvements such that standard image quality can be obtained when using 50% fewer counts regardless of patient body mass index". Another example is Precision DL (from GE Healthcare), which is designed to improve the small, low-contrast lesion detectability.

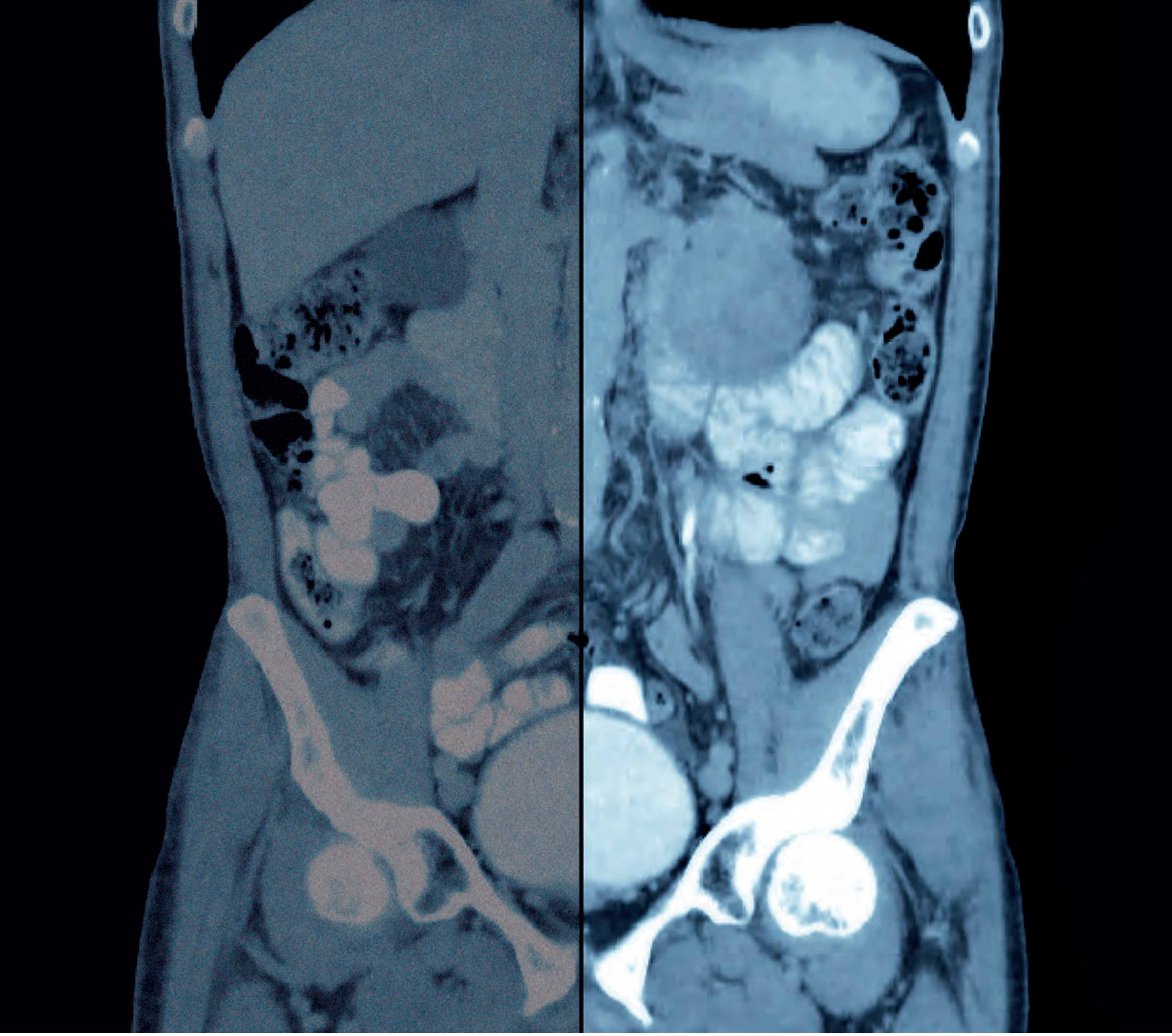
Whilst both resolution improvement and denoising methods certainly show promise in facilitating faster or lower dose scanning, for the most part they currently lack comparison with current state-of-the-art methods and there are concerns associated with "hallucinations" when generative AI algorithms are employed.

Jargon explainer	
Image reconstruction	Conversion of acquired raw data into a useful image.
Sinogram	Raw data acquired during computed tomography imaging, each row of data is acquired at a different angle of rotation.
FDA	Food and Drug Administration, regulatory body for medical devices in the US.
Ground truth images	Reference data that is assumed to be definitively true, e.g. images that have been confirmed to show tumour. Used for training the AI algorithm and to test how accurately the AI can reproduce the ground truth.
De-noising	Removing noise from an image.
Segmentation	Dividing an image into areas of interest, e.g. outlining a particular organ on a CT scan.
PET-CT	Imaging modality combining the use of radiopharmaceutical positron emission tomography for functional imaging with the anatomical imaging of X-ray computed tomography.
SPECT	Single photon emission computed tomography. Radiopharmaceuticals are taken up by specific tissues, emitting gamma rays which are used to make a 3D image.
^{18}F-FDG PET-CT	A specific type of PET-CT scan employing a radiopharmaceutical that mimics sugar, enabling areas of high metabolic activity to be imaged.
^{68}Ga-PSMA PET-CT	A specific type of PET-CT scan employing a radiopharmaceutical that can attach itself to the chemical processes associated with prostate cancer, enabling the location of prostate cancer cells to be imaged.
Radiomics	Analysis of quantitative features extracted from areas of interest in an image. These can be used to characterise and identify medical features not visible to humans.
^{177}Lu-PSMA radionuclide therapy	A radiopharmaceutical used for prostate cancer treatment; the molecule binds to the tumour tissue and delivers a localised radiation dose to kill the cancer cells.

Segmentation algorithms

Moving further along the imaging pathway, DL-based segmentation algorithms show potential for superior precision and significant time savings in volume segmentation, with numerous software providers now supplying commercially available AI-driven outlining tools. Here, CNNs are trained on large datasets of images, where each image has manually labelled ground truth segmentations. The trained model can then be applied to new, unseen images to automatically generate accurate segmentations. These methods have shown good performance in various applications, including image registration, lesion detection in PET-CT and organ delineation in gated cardiac blood pool studies and myocardial perfusion imaging where outlining of the left ventricle or myocardium is required. Whilst their adoption has facilitated faster and more consistent quantitative analysis and imaging biomarker extraction, they still require human-in-the-loop verification and correction. One area where combinations of new AI tools might be particularly beneficial is for dosimetry in molecular radiotherapy, where there can be the need to register several sets of images from different time points and to then segment the target volumes and organs at risk. With a limited

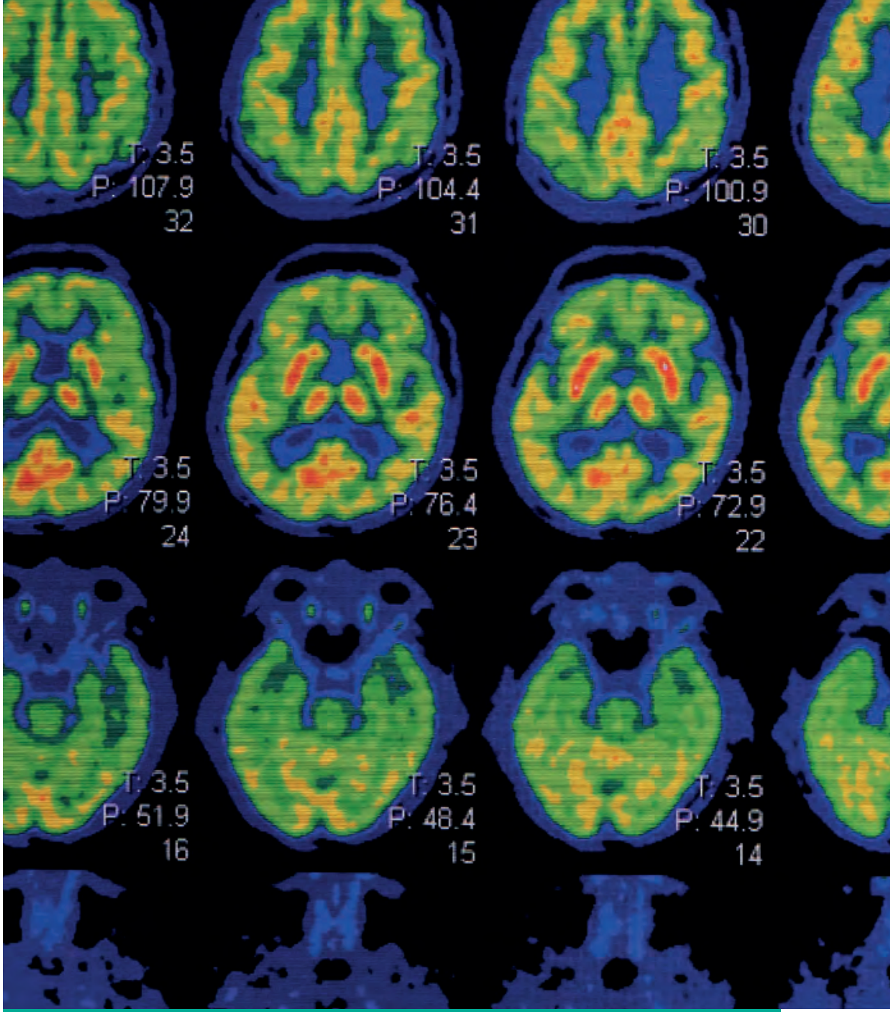
> "EXAMPLES IN THE LITERATURE OF APPLYING DL TO PET-CT IMAGES AND ML TO PET-CT RADIOMIC FEATURES TO PROVIDE CLINICAL DECISION SUPPORT TOOLS ARE CONTINUING TO GROW IN NUMBER AND INCREASE IN ACCURACY



physics workforce and a potential for a significant increase in patient numbers, AI tools might be crucial for such dosimetry to be implemented efficiently, accurately, and to be adopted as the standard of care.

Generative adversarial networks

Of all the areas currently being researched, it is probably DL-based image synthesis using generative adversarial networks (GANs) that represents the most novel and speculative application. GANs have the potential to be used for cross-modality image synthesis whereby it is possible to generate synthetic images in one modality based on the information obtained from another modality. In nuclear medicine this has been explored in the generation of attenuation correction CT images, from MRI images for use in PET(CT) imaging thus negating the need to acquire a CT. Other research has demonstrated the potential to generate PET cerebral blood flow images from MRI images. However, the safe implementation of GANs for cross-modality image synthesis in nuclear medicine imaging faces several considerable challenges to avoid misinterpretation or incorrect decisions. These include the requirement for large amounts of diverse and high-quality data for effective training, the susceptibility to generating artifacts or unrealistic features in synthesized images (hallucinations) and the need for interpretability and validation to ensure reliability and understanding of the limitations and uncertainties associated with synthetic images.



AI APPLIED TO IMAGE DATA

Deep learning (DL) algorithms: applied directly to images by training CNNs on large datasets of images annotated with ground truth patient outcomes. Trained algorithms are then used to make predictions of outcomes from unseen images.

Machine learning (ML) algorithms: applied to metrics already extracted from images known as "radiomics", that represent aspects such as texture, intensity, shape, or size of a specific area of interest in the images. First, the ML algorithms are trained on datasets containing these radiomic features and their corresponding ground truth patient outcomes. Trained algorithms are then used to make predictions of outcomes from radiomic features of new images.

More than meets the eye

Whilst still very much in the research phase, the clinical uses of AI in nuclear medicine could, in time, prove to be highly impactful for patient outcomes via AI-driven clinical decision support tools. The main areas of application are the use of nuclear medicine images e.g. PET-CT in diagnostic predictions to aid clinicians in reporting and prognostication and stratification for disease assessment, personalised patient therapy monitoring and response assessment. For all these areas there are two main approaches, DL algorithms applied directly to images and machine learning (ML) algorithms applied to metrics extracted from images (radiomics).

DL applied directly to images offers a more end-to-end learning approach with high accuracy and the ability to capture complex patterns without the need to manually create and choose input features. On the other hand, ML applied to quantified image metrics requires manual feature extraction and engineering (although this in itself could be automated using AI-driven segmentation discussed earlier) but offers the advantage of greater interpretability and potentially lower data requirements.

Clinical areas

The clinical areas in nuclear medicine where these methods have seen notable successes reported in the literature are neurology, cardiology and oncology. In neurology, AI has been demonstrated to aid in the interpretation of PET and SPECT brain images for neurodegenerative diseases. Studies have shown high test accuracy in discriminating between Parkinson's disease and normal scans, as well as in distinguishing between Alzheimer's disease and normal controls. In cardiology, AI has been applied to predict major adverse cardiac events from myocardial perfusion imaging (MPI) with a recent joint European Association of Nuclear Medicine and European Association of Cardiovascular Imaging position paper highlighting that AI-based software tools are expected to support physicians in interpreting imaging data in clinical routine.

In oncology, examples in the literature of applying DL to PET-CT images and ML to PET-CT radiomic features to provide clinical decision support tools are continuing to grow in number and increase in accuracy. Whilst there are too many to list exhaustively here, examples include ML applied to ^{18}F-FDG PET-CT radiomics to potentially replace or aid a histological diagnosis when biopsy is difficult, DL used on pre-treatment ^{18}F-FDG PET-CT images for prognostication for lymphoma patients and ML applied to ^{68}Ga-PSMA PET-CT radiomics to predict response to ^{177}Lu-PSMA radionuclide therapy. In addition to the use of PET-CT, research has demonstrated that AI can be used in ^{99m}Tc bone scanning to improve interpretation accuracy and save time, with one algorithm performing slightly better than experienced physicians.

Finally, DL methods have also been used to replace Monte-Carlo simulation for absorbed dose estimation in radionuclide therapy and improve dosimetry estimation from SPECT or PET measurements. Whilst dosimetry methods have been developed to calculate absorbed dose distributions, estimation and extrapolation of pharmacokinetics still pose challenges in the clinical setting. More speculatively, it has been suggested that AI may eventually be able to uncover the relationships between pre-treatment imaging data, clinical data, such as blood test results, demographic

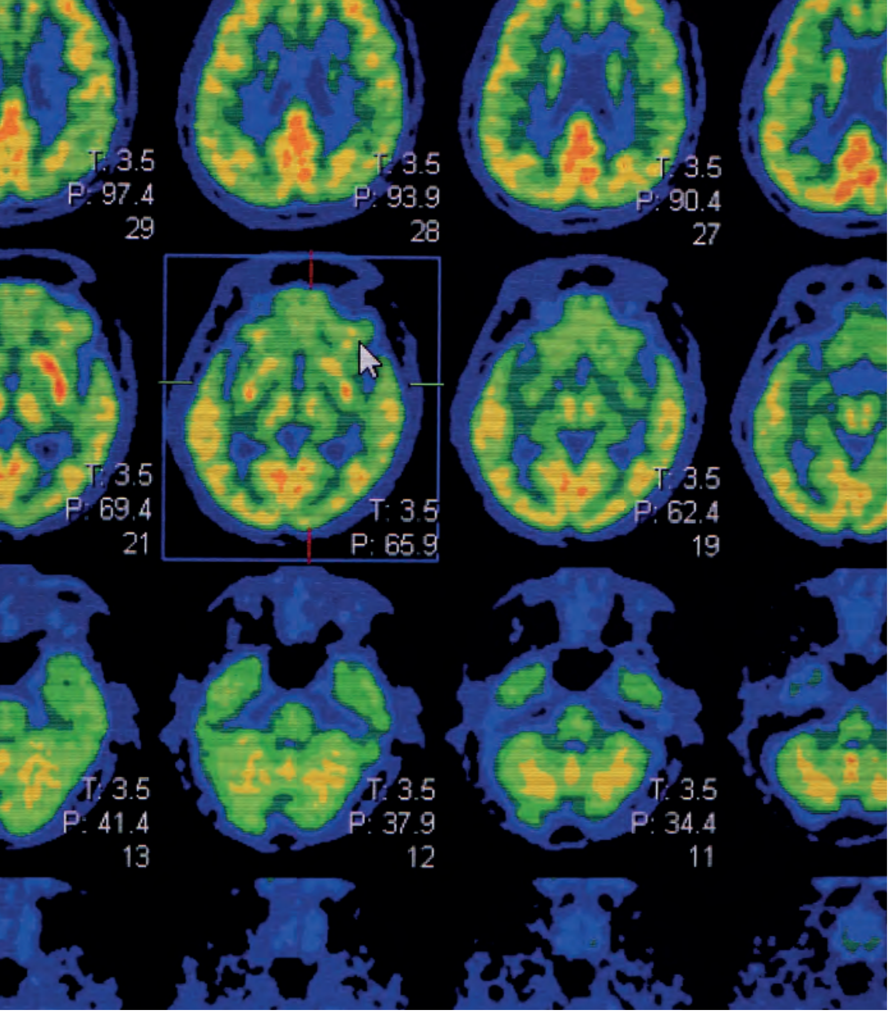
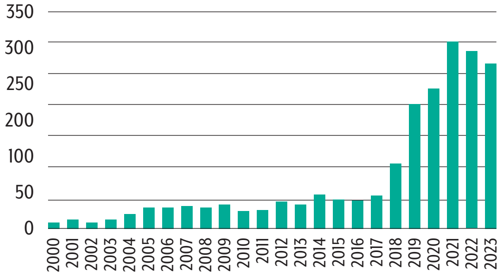


Figure ❷: Journal publications per year: (artificial intelligence) OR (machine learning) OR (deep learning) AND (nuclear medicine)



Challenges of developing and deploying AI in healthcare
Ensure data privacy, consent and security
Ensure ethical and regulatory compliance
Improve public trust and engagement
Mitigate algorithmic drift over time, bias and data inequality
Encourage explainable AI (XAI/interpretability)
Address growing skills gap and training needs

"THE UNHELPFUL RHETORIC AROUND AI STEALING JOBS AND REPLACING MEDICAL SPECIALISTS HAS FADED AND THE BODY OF EVIDENCE DEMONSTRATING AI'S POTENTIAL… IS GROWING

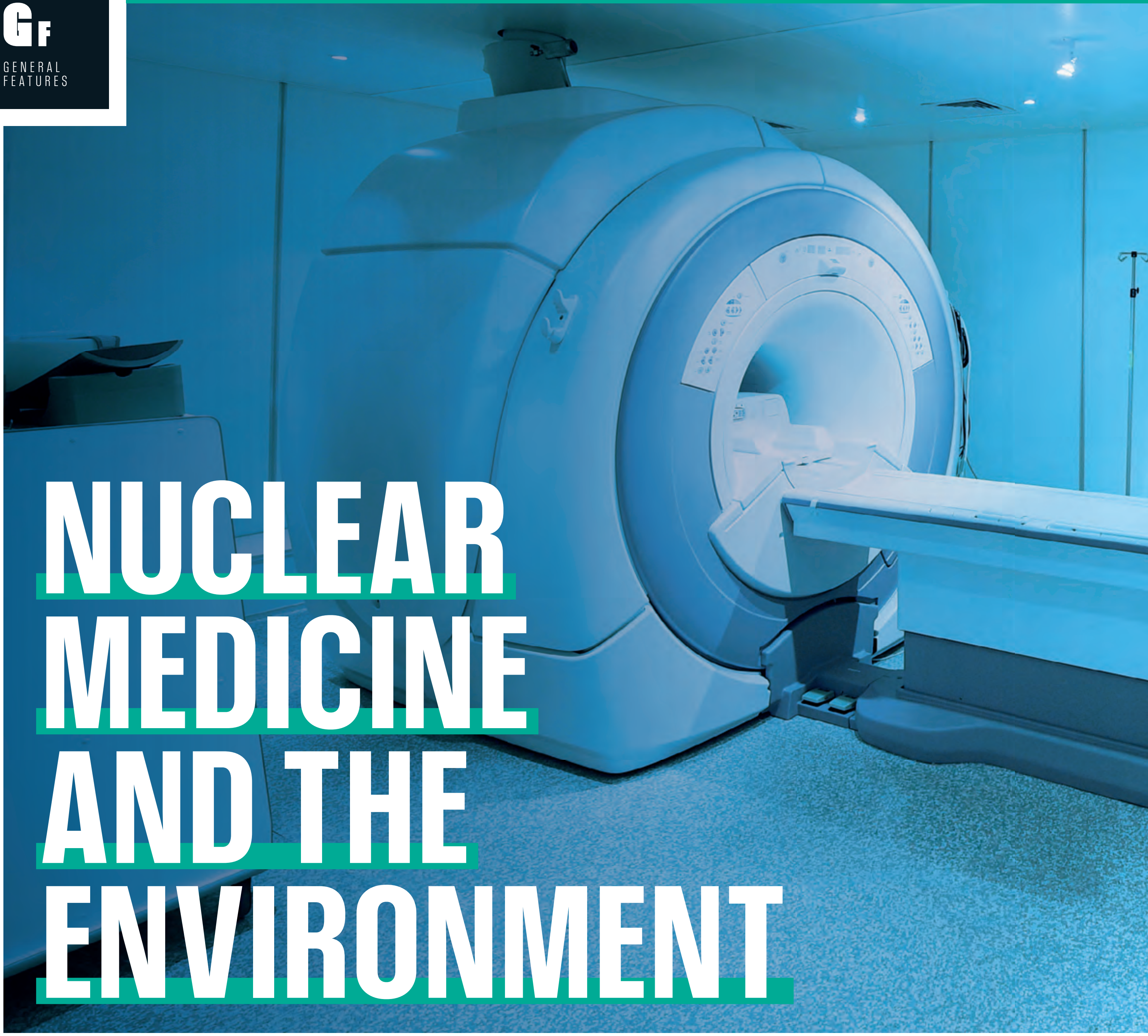
data and the absorbed dose distribution from radionuclide therapy.

Challenges and ways forward

Whilst we have highlighted some specific limitations associated with each of the applications discussed, there exist several overarching challenges and questions relevant to any development or deployment of AI in healthcare. To achieve widespread adoption, considerable work is needed to address these before the full potential of AI is realised in a manner acceptable to both healthcare professionals and patients. Medical physicists, with our unique set of technical skills and legislative responsibilities, must play a key role within a multidisciplinary approach to this work for AI to be developed, deployed, monitored and maintained safely and effectively.

In trying to decide how to navigate these challenges, educate and prepare themselves for a future in which AI plays an increasingly influential role in everyday work, individual departments will be faced with their own unique set of opportunities, obstacles and considerations. It is important to equip nuclear medicine departments with a clear understanding of this landscape. Fortunately, the unhelpful rhetoric around AI stealing jobs and replacing medical specialists has faded and the body of evidence demonstrating AI's potential to augment job roles and enhance productivity is growing. In nuclear medicine we must embrace the opportunities and collaboratively overcome the challenges to enable the transformative potential of AI to improve patient care, reduce costs and increase efficiency throughout the entire patient pathway.

***Richard Meades** is the Radionuclide Therapy Lead Physicist in Nuclear Medicine at The Royal Free London NHS Foundation Trust and Chair of IPEM's AI Group. Any members who are interested in any aspect of AI in MPCE and healthcare can join IPEM's AI and Machine Learning Community of Interest to start, or get involved in, discussions.*



NUCLEAR MEDICINE AND THE ENVIRONMENT

What can the healthcare sector learn?

Nuclear Medicine Physics Technician **Jack Johnson** looks at areas including equipment usage, radioisotope transport and single-use materials to explore how we can reduce our carbon footprint.

Despite the recent international agreement at COP28 to begin the transition away from fossil fuels, much work still needs to be done to curb the damaging effects of carbon emissions. The healthcare sector in particular still remains a stubbornly large contributor to greenhouse gas emissions, with NHS England contributing more than 40% of the public sector's carbon emissions, and the NHS producing 4–5% of the UK's total emissions.

Physicists and engineers are well placed in the drive to reduce emissions to reduce

IMAGES: SHUTTERSTOCK

healthcare emissions, with IPEM's Environmental Sustainability Group publishing helpful advice for departments wishing to reduce their carbon footprint, but nuclear medicine often goes unmentioned in the climate debate. Nuclear medicine still has a drastic impact on carbon emissions within radiology – one PET/CT scanner alone produces the equivalent of over 15,000 kg in CO_2 emissions (CO_2-eq) a year, which is equal to the average yearly emissions of over 10 European households, and a single stress-SPECT scan can produce 20–30kg CO_2-eq. This leaves the question – how can nuclear medicine reduce its carbon emissions, and how can these techniques be applied to the healthcare sector as a whole?

Equipment usage

When approaching the nuclear medicine environmental question, one starting point is the carbon footprint of equipment usage. Attention must be given to minimising gamma camera energy consumption. Calibration times for PET cameras are often in excess of 12 hours, meaning that equipment is perpetually left on overnight and during out of office hours. Without this calibration constraint, colossal reductions in electricity usage could be made, typical PET gamma cameras have yearly energy consumption values of over 52,000 kWh, and switching cameras off for short periods when not in use (such as during meal breaks and patient turn-around times) could save the operating hospital 3,550 kg CO_2-eq and over £3000 a year, according to research. However, significant gains can be made by switching off other camera components. Almost every current gamma camera is combined with a CT component, to acquire both functional and anatomical images. Some CT scanners can be switched into stand-by mode, with the gantry off and camera on, or even better, switching both camera and gantry off overnight and on Sundays can produce energy savings amounting to approximately 14,000 kWh per year per CT camera, according to Canadian estimates.

Technology is beginning to provide solutions to this energy usage issue and new PET/CT scanners from GE Healthcare can reduce power consumption by 50% when in standby mode, but this is perhaps an example of curing but not preventing the power problem – manufacturers should be urged to consider the larger energy consumption picture. This philosophy of minimising electricity usage can easily be applied to all areas of healthcare – trust IT departments, for example, can install software that automatically switches off computers outside normal office hours. Cutting unnecessary equipment usage across modalities can produce significant results; switching off an MRI scanner overnight and on weekends can save nearly 8,000kg CO_2-eq each year. The healthcare sector should strive towards effective equipment usage, whether through alternative, efficient techniques, such as single time point SeHCAT or single sample GFR exams, or even simply optimising patient turnaround time.

"ATTENTION MUST BE GIVEN TO MINIMISING GAMMA CAMERA ENERGY CONSUMPTION

Work can also be done in expanding the usage of low-carbon modalities. Clinicians are often limited in their choice of exam, leaving little room for considering the carbon footprint of each investigation. Further research into expanding alternative exams, such as stress-ultrasound, which only produces 2-3kg CO_2-eq per study, to a wider range of clinical scenarios could go far in reducing healthcare carbon emissions. It is crucial for the healthcare sector to minimise equipment electricity use where possible, promote carbon-reducing technological developments and explore efficient equipment usage methods to begin to tackle healthcare emissions.

Radioisotope production and transport

An essential element in the reduction of the carbon footprint of nuclear medicine is the contribution of radioisotope production and transport. Currently, the UK has no home-grown supply for Mo-99, which is required for Tc-99m production, thus increasing transport emissions as isotopes are imported from abroad. Many options have been proposed to address the demand for imported radioisotopes. New nuclear reactors are one solution, but the Nuclear Innovation and Research Advisory Board estimates that building a new research reactor in the UK capable of producing medical isotopes would take ten years and

"EVEN A STREAMLINED PROCESS CAN INVOLVE USING RADIOPHARMACEUTICAL AND SALINE SYRINGES, A CANNULA, PAPER FOR THE PET COUCH, THREE PAIRS OF PLASTIC GLOVES, TWO SYRINGES, AND A CELLULOID MAT

cost £250–400m, and the carbon cost required to build such a reactor may outweigh the savings made in transportation. In Canada, the TRIUMF research centre demonstrated the capability of using cyclotrons to produce Tc-99m directly, thus cutting Molybdenum-99 out of the supply chain entirely, and Alliance Medical is producing these cyclotrons for use in the UK. However, many carbon-saving improvements can be made by smaller and more affordable steps at the trust level.

The Administration of Radioactive Services Advisory Committee has noted that introducing weekend working in nuclear medicine departments would allow for more efficient usage of Tc-99m generators, but according to the British Nuclear Medicine Society this is likely to place further strain on an already overstretched workforce and would need to be fully funded to be effective.

Examining steps along the radioisotope supply chain can also be beneficial and radiopharmaceutical staff across the country have made significant efforts to introduce sustainability into supply chains. GE healthcare, for example, has now introduced a scheme to collect and recycle lead and plastic pots used to transport I-123 capsules. This drive towards reusing materials in supply chains can also widened to other areas of radiology, with many hospitals now collecting and recycling unused iodine contrast after a successful trial scheme in Norway.

Patient and staff travel

In addition to examining radioisotope transport, patient and staff travel are also areas for improvement. Total staff and patient transport take up approximately 17% of total NHS emissions, and with more than 20,000 vehicles in the NHS England fleet travelling 460 million miles per year, staff travel and commissioned services have a direct and sizable contribution to the 36,000 deaths a year in England from air pollution. Whilst NHS England aims to cut staff travel emissions in half by 2033 through more sustainable staff transport and electrification of personal vehicles, more immediate steps can be taken to address this issue. Video consultations before molecular radiotherapy appointments, for example, could eliminate at least one patient round trip, and issuing pre-exam capsules by post could also save further unnecessary journeys to hospitals. The ethos of reducing patient travel could easily be expanded to the healthcare sector as a whole, hospital trips becoming a "one-stop-shop", where appointments, blood tests and imaging examinations are completed consecutively, thus preventing excess travel for patients. During radium therapy treatments, for instance, bone exams, blood studies and consultations could be undertaken in succession, saving both excess patient travel and administrative work.

Single-use materials

Nuclear medicine can also minimise its environmental impact by reducing single-use materials. Even in a streamlined process one F-18 FDG PET/CT procedure can involve using radiopharmaceutical and saline syringes, a cannula, paper for the PET couch, three pairs of plastic gloves, two syringes, and a celluloid mat. This is perhaps part of a much wider problem in the medical industry, with 42% of all medical plastics in Europe being incinerated and incinerators emitting more CO_2 per megawatt-hour than coal, gas or oil power plants. When this is combined with the additional problem of minimising operator exposure to radiation, the single-use plastic issue becomes a far

greater challenge. Due to optimisation requirements in IR(ME)R2017 legislation, staff doses must be kept as low as reasonably practicable, meaning that plastics and personal protective equipment are frequently discarded due to contamination risk. However, meaningful steps can be taken to reduce this – Imperial College Healthcare NHS Trust utilises reusable sterile gowns in interventional radiology, and radiopharmacies across the UK have recently introduced biodegradable plastic clean room gowns. Many areas can optimise recycling practices, with a study from Leiden concluding that simply correctly separating plastic and paper recycling used during a PET procedure can lead to a 64% CO_2-eq reduction.

Again, minimising waste should be thought of as a healthcare-wide issue. Greater usage of paper-free patient correspondence is one approach, albeit this may prove challenging to those with certain accessibility requirements. Ultimately, it is the responsibility of physicists and engineers to review ways of reducing single-use plastics and ensure that these steps are swiftly executed, and not left languishing as ideas for another time.

True emission values

Finally, it is worth noting the lack of available data on nuclear medicine's carbon emissions. Whilst the carbon footprint of MRI and computed tomography have been published in peer-review articles, the true emission values for nuclear medicine and molecular radiotherapy emissions remain largely undocumented. It is essential that further data gathering work be undertaken, particularly within the UK, for scientists and engineers to truly grasp the scale of the medical physics emissions problem and what reasonable steps can be taken to address it. An appetite for decarbonisation certainly exists in the medical physics community – in 2021, the President of the American Board of Radiology stated that practitioners "must urgently consider the role of imaging in climate change and mitigate imaging's harmful environmental impact". And 92% of UK patients in a 2022 survey believe that sustainable healthcare operations are important, proving that there is both a public and professional desire for change, despite the lack of data on the issue.

A joint effort

So, what can the rest of medical physics learn from nuclear medicine? Supporting environmental organisations such as IPEM's Environmental Sustainability Group is key to a joint effort in tackling climate change. A wide-spanning study of the carbon footprint of molecular imaging is currently ongoing, but requires input from several hospitals to be effective, thus engaging with these studies is an easy and impactful way to get involved. Secondly, supporting research developments that minimise equipment energy consumption would go far in the world of greener medical imaging. Equipment with short start-up and calibration times would ensure that it is not left perpetually on standby and consuming electricity, and looking into efficient exam procedures could thus both save money and minimise carbon emissions for the department. Whilst nuclear medicine can examine its radioisotope supply chain emissions, this philosophy of studying the impact of transportation can go a long way in building a more environmentally friendly NHS, by cutting down on excess patient and staff travel. Finally, reviewing trust-level procedures on single-use plastic is essential, and easy carbon savings can be made by a greater emphasis on recycling and biodegradable materials. Physicists and engineers have the experience and desire for a greener NHS, but a conscious and sustained effort is required to keep healthcare emissions under control.

***Jack Johnson** is a Nuclear Medicine Physics Technician at the University Hospitals of Leicester NHS Trust*

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FEMALES ARE DIAGNOSED ON AVERAGE FOUR YEARS LATER THAN MALES IN CONNECTION WITH 770 TYPES OF DISEASES

GENDER-DEPENDENT RADIOTHERAPY

Implementing from first principles

Clinical Scientist **Maryam Akhtarini** argues that there are gender-based, deep-rooted issues in radiotherapy that need to be addressed.

In the last few years, almost all the work in radiation oncology has related to the optimal delivery of radiotherapy in terms of technology, quality assurance and morbidity reducing approaches. Radiotherapy has become increasingly technologically complex. But do we assume that our dose, fractionation and multidisciplinary interactions are understood and still valid?

Looking at these from first principles, one can find assumptions from the 1920s that are still in place, based on, for example, experiments carried out in Paris on male sheep and male rabbits, in which the testes (sterilisation) was regarded as a model of a growing tumour and skin as a dose limiting normal tissue. This led to our fractionation approach and is empiric prescribing (relies solely on observation and experiment).

Huge inconsistencies

Sensory (five senses) empiricism begins with the word "observe". There is no injunction to use a priori reason and logic first, nor is there a rule for thought to obey the principle of sufficient reason (explanation). So, if part of reality is unobservable, the scientific method will automatically fail to tell us. Empiricists have chosen to restrict "understanding" to what is observed and experienced. It is possible though to have rational and logical certainty in a mathematical reality, as mathematics uses pure concepts.

Another huge inconsistency that needs to be resolved is that females are diagnosed on average four years later than males in connection with 770 types of diseases. In cancer, females are on average diagnosed

IMAGES: ISTOCK

> **"SEQUENCING OF THE HUMAN GENOME REVEALED THAT CANCER IS NOT A SINGLE DISEASE BUT MULTIPLE DISEASES**

2.5 years later than males. The prevalence of this bias is mounting – in cancer of lung, kidney and bone marrow transplants.

Females are also more likely to die from heart attacks, react poorly to prescription drugs, have average pains and symptoms dismissed, misdiagnosed and neglected, and be accused of being over-anxious, mislabelled as depressed or told their symptoms are all in their heads by physicians. There are physicians also, who work tirelessly to change the system. We can no longer use the one-size-fits-all model.

Why sex difference bias exists?

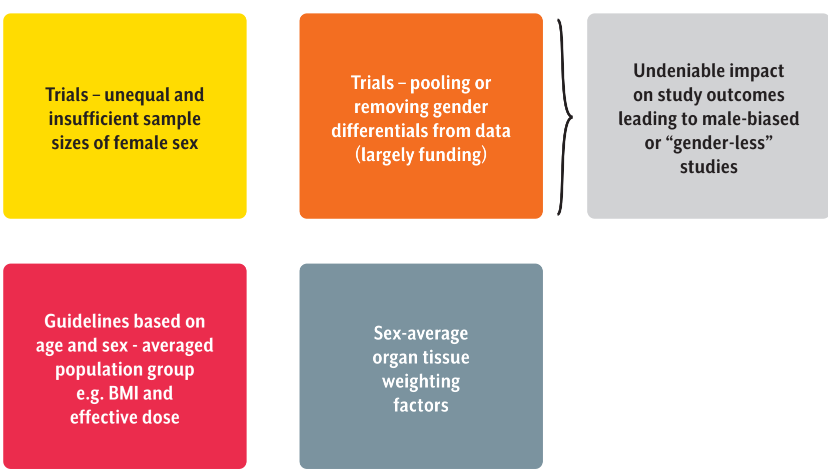
- Physicians used to think any health differences between men and women were strictly isolated to reproductive. We know that there are sex (DNA) differences in every health condition and organ.
- Medical school (and scientific education) was setup to teach that a 70kg male was the norm, with everyone else a "variant" of that. Men and women attend the same medical schools and have the same lack of education in this area
- If results aren't reported by sex as a biological variable, it is a problem. In 2024, there's a lot of sex difference information hidden in pooled data. But without a subanalysis (where you look at the groups separately to see if there are sex differences), research remains unequal, and unequal care remains. Females are harmed by practicing one-sex or gender-blind medicine.

Also, sequencing of the human genome revealed that cancer is not a single disease but multiple diseases, inherently different at a genetic level (or to extend further – the quantum waveform level). This realisation has led to the era of precision medicine. Radiotherapy is still reliant on patients receiving uniform doses. Genomic-based radiation therapy is needed.

Introduction

The assumption from clinical trials of the reference adult (male, 70kg, Caucasian, 25-30y) is untrue. Consequently, a gender data gap exists that results in less than best practice evidence. Scientists, when applying statistical manipulation to the collected data, often pool or remove gender differentials. Otherwise, studies would need twice the number of patients, time and money. As a result, clinical knowledge to this day continues to be pulled from male-biased or "gender-less" studies. This means only male personalised medicine exists – for anyone else, it is less accurate.

❶ Status quo



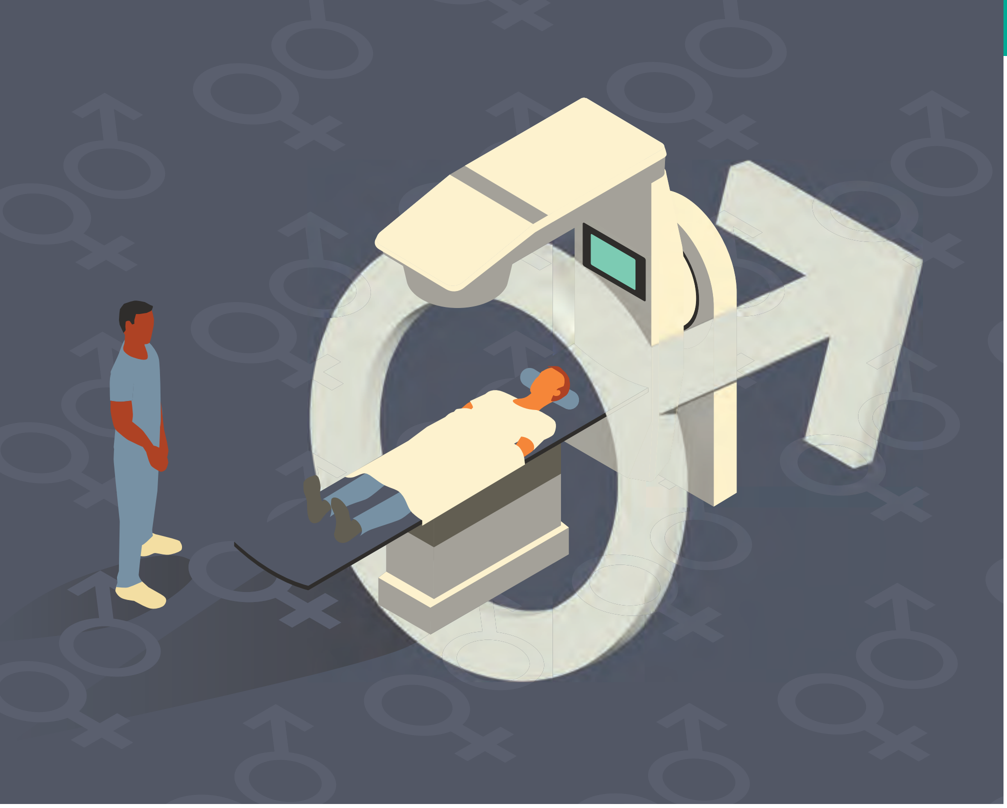
Status quo

In radiotherapy, a small but significant difference in radiosensitivity (from a tumour control and normal tissue toxicity perspective) between sexes has been well documented. Yet most radiotherapeutic guidelines are based solely on age and sex-averaged population group data, such as a person's BMI and effective dose. Rather than demographic subgroups such as sex, age, hormonal status and race.

Radiotherapy uses empiric prescribing and operates under the assumptions that patients have constant homogeneous biology and uniform radiosensitivity. These assumptions are untrue. The standard total doses for control of subclinical, microscopic and macroscopic disease (50, 60 and 70 Gy) were established in the 1960s on the basis of tumour control probability (TCP) models for patients with head and neck cancer. The development and publication of these models has gone unmodified for more than 70 years, whilst the fractionation approach from the studies of male sheep and rabbits is more than 100 years old. This one-size-fits-all approach is biologically inaccurate and results in increased and decreased dosing – 2 Gy delivered doesn't always equal a 2 Gy effect and a high dose of radiation doesn't guarantee a high radiation effect. To date, personalised radiotherapy has meant anatomic personalisation (dose shape).

Evidence and results

Females are generally more radiosensitive (long term), more likely to be cured of cancer but have worse side effects (~2-fold greater toxicity). Plus, a ~2-fold risk of secondary solid tumours, which varies by



organ and age at exposure. Males are generally more radio-resistant, have fewer side effects, but shorter long-term survival rates. This is not considered in international guidelines for radiation dosages.

Therefore, in clinical trials, non-sex related cancers should be considered as biologically distinct groups (equal sufficiently large sample sizes), for whom specific treatment approaches merit consideration and further investigation.

The fact that oncological research and practice is still largely sex and gender blind, may result in prescription of sub-optimal treatment doses and inaccurate long-term risk assessment. In tumour biology, tumours are found to be dynamic and heterogenous.

Solutions

- ***Clinical trials and international guidelines***

Trials should have equal and sufficient samples of each sex to detect differences and results should be stratified by sex and hormonal environment. Also, guidelines should be based on sex, age, hormonal status and race and there should be sex-stratified organ tissue weighting factors.

- ***Personalised therapeutic and radiological models***

Novel therapeutic dose model: This is an optimised risk/benefit model that uses genomics, lifestyle factors and physiological variations to help determine radiosensitivity and guide individual dosing. This can be done using

> **" MALE-CENTRIC MEDICINE AND ONCOLOGY ENDANGERS FEMALE HEALTH**

radiogenomics and biobank data.

Novel radiological risk index model: This model addresses the long-term radiation risks and provides insights into individual adverse effects, by screening for toxicity and secondary cancer risk.

This model is necessary as people request and need individual risk assessments after accidental irradiation e.g. the 2011 Fukushima nuclear accident. Such vital information is not available, as current effective dose population group data does not provide a measure of individual risk.

For instance, with a 20-year-old female accidentally exposed to 20 mSv radiation, if a personalised risk index score is estimated at ~5-6 due to age, sex and DNA damage mutation, her personalised dose will be ~100-120 mSv. So, her radiation risk is comparable to a risk of 100mSv, rather than 20 mSv in terms of effective dose at population level. To minimise future health risks, this woman can, as she matures, select appropriate medical check ups for cancer in a balanced fashion.

Genomic adjusted radiation dose (GARD): GARD is derived from gene expression-based radiation-sensitivity index (RSI) and physical dose using the classic linear quadratic model. It is a US-licenced biological model which operates as a personalised optimised therapeutic ratio.

- ***Dynamic heterogenous tumour biology***

Tumour biology is heterogenous and dynamic. For instance, radiotherapy elicits changes to the tumour microenvironment (TME) that either augment or interfere with therapeutic response. Treatment resistance factors such as hypoxia and diapause may be found in the many cancer types found within any given cancer. Useful tools in measuring hypoxia e.g. MR-Linac and dose painting.

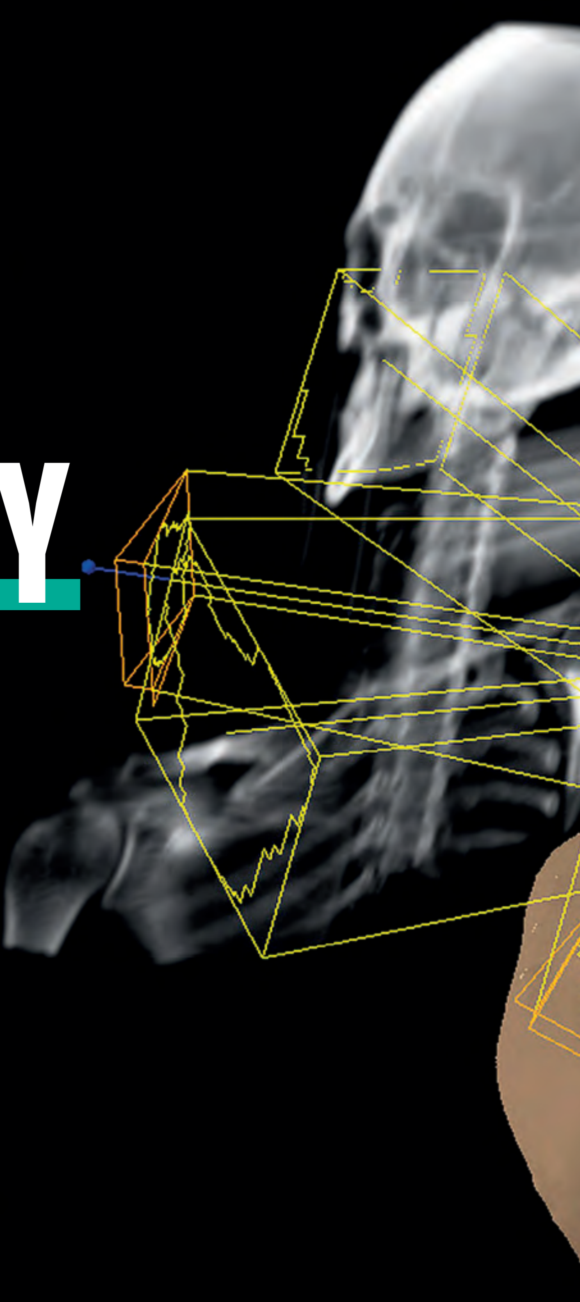
Conclusion

In medicine, clinical trial data gaps have led to a fundamental lack of understanding of the influences of sex on the prevalence, presentation and progression of diseases, which results in serious health inequalities. Male-centric medicine and oncology endangers female health. Radiation oncology operates on a null hypothesis: all patients are biologically homogeneous and uniform radiosensitive responses. Radiotherapy delivery is physically accurate, but biologically imprecise.

Precision medicine focuses on biology-driven rather than empiric, therapeutic approaches. This era issues a new paradigm – assumptions need to be updated by acknowledging biological sex to deliver biologically optimal radiotherapy doses.

We need gender-dependent radiotherapy with accurate clinical trials that include sex and gender, updated international guidelines, sex stratified organ tissue weighting factors to guide dosing and novel therapeutic and radiological models. This will lead to better dosing, less toxicity and a better quality of life for those involved. Addressing these deep-rooted biases and challenging the status quo is vital to improving health outcomes for the female population.

***Maryam Akhtarini** is a freelance Clinical Scientist working in radiotherapy physics*



WHEN IS A RADIOTHERAPY PLAN ACCEPTABLE?

Senior Clinical Scientist **Russell Dawson** analyses the results from a national survey on plan acceptability for radiotherapy.

Earlier this year I found myself in a debate – when is a radiotherapy plan acceptable?

Each patient receiving external beam radiotherapy in the UK will have an individual radiotherapy plan. For complex treatment sites these will often be inverse-optimised. We tell the treatment planning system what we want, and it will do its best to create a plan that meets these objectives.

Radiotherapy planning is a complex, safety-critical process, so each plan will have an independent check by a trained checker, as per *Towards Safer Radiotherapy*.

If the plan is acceptable, it will move on towards treatment. If the checker feels that the plan is unacceptable, the checker will often ask the original planner to amend it. This maintains independence between the planner and checker.

How does the checker decide what is "sent back"?

Some cases are straightforward – the plan is unsafe or undeliverable. Perhaps the plan would cause the linac to collide with the patient, or deliver a dangerous radiation dose to a critical organ. These cases must always be corrected.

Some cases are not so straightforward – the plan is adequate, but it could be better. Perhaps the planner failed to "push" the optimiser hard enough, and so the nearby organs are getting more radiation dose than necessary. Or, even more subjective, the planner focussed on preserving one organ, but neglected another organ more than the checker would have liked.

We could change every plan where we think an improvement is possible. But modifying plans is not without its own risk. Altering radiotherapy plans can also introduce delays that might force tasks downstream to be rushed. In extremis, we may need to delay the patient starting treatment while the plan is corrected.

Plan checking is a significant resource commitment, and checking processes which search for "can do better" changes

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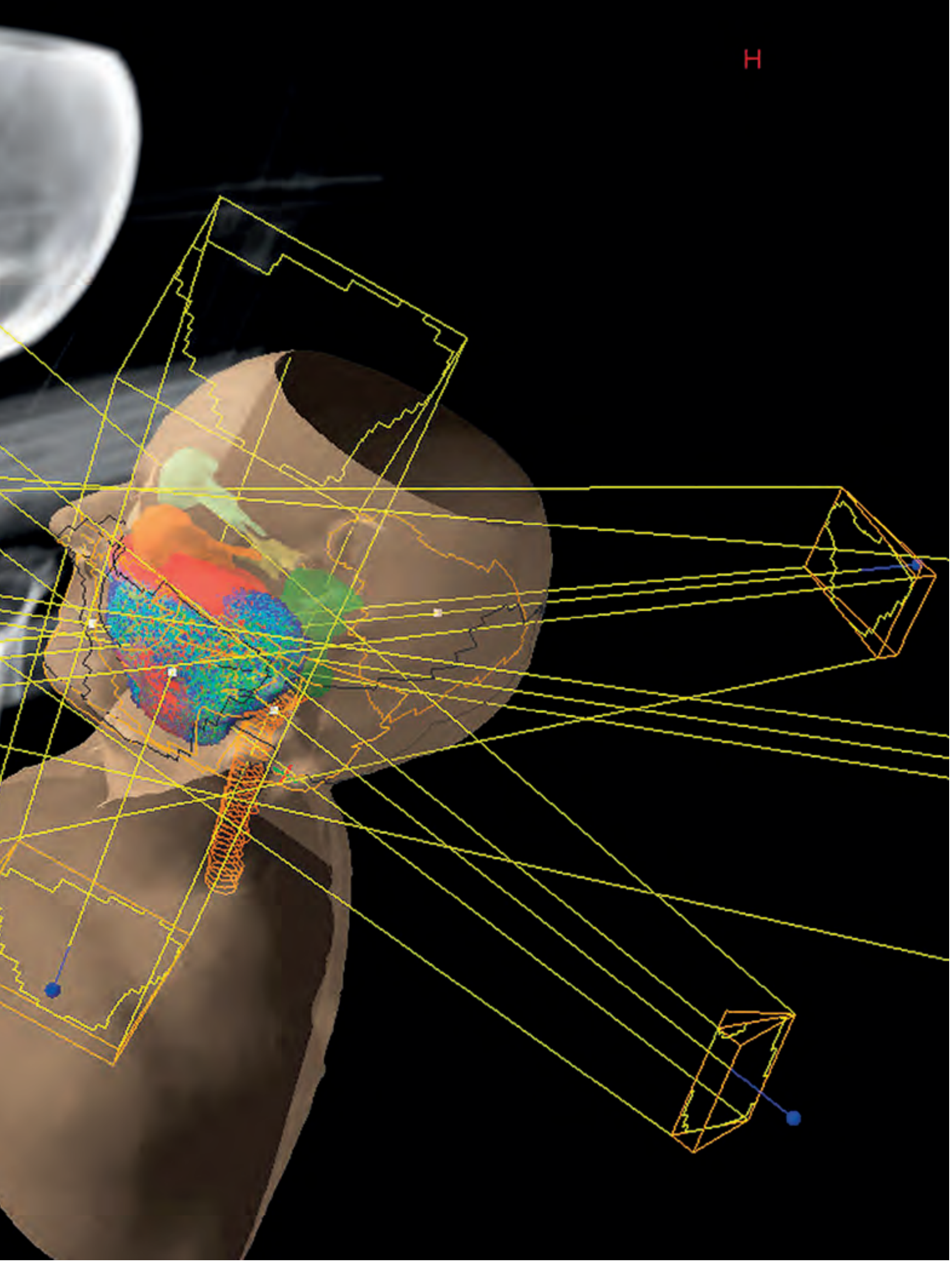


will take longer than simple checks for safety and deliverability. At my centre we estimated that a "can do better" check can more than double the time required to check the plan.

As healthcare professionals, we strive for excellence in patient care, but the question remains: When does the pursuit of "better" become the enemy of "good"? Even searching for those minor savings isn't a neutral activity. Time spent checking clinical plans is time not spent on quality improvement work.

As US statistician Harold Dodge said: "You cannot inspect quality into a product."

Arguably, if you want to improve the quality of radiotherapy plans, you should check them less rigorously.

The survey

Clearly, we weren't going to solve this problem in-house. I knew the spread of opinion at my centre, but what was the national consensus? In April 2023 we invited the UK MED-PHYS Mailbase to contribute to an online survey.

We asked respondents about the process for checking head and neck radiotherapy plans. We deliberately chose head and neck for two reasons:

1. It's a site that physicists are most likely to be directly involved in.
2. It's a site where compromise is often required.

We asked respondents what they checked, and how important different parts of the plan checking process were. We also asked how people decide if a plan needs to be rejected and returned to the planner. Over three weeks we received 52 responses from 34 centres, mostly in the UK, but with contributions from as far as New Zealand.

The results

Variability in optimisation practice

Some areas have a reassuring national consensus. Everyone considers the target coverage to be an essential part of a plan check. Some elements had more variation, a considerable number of respondents did not interrogate the optimiser as part of the check ❶. To quote one responder: "Errors in optimisation are acceptable if the dose distribution is acceptable".

Structures under scrutiny

Related to this was the choice of what structures required checking ❷. Checking planning target volumes was unanimously important. However, a sizable number did not check optimisation structures (hots, colds, etc.). For the uninitiated – optimisation structures are parts of organs close to targets. They are created just to tell the planning system where to focus on achieving objectives.

"

ERRORS IN OPTIMISATION ARE ACCEPTABLE IF THE DOSE DISTRIBUTION IS ACCEPTABLE

Figure ❶ If you are happy with the dose distribution, how important is it to check the plan is optimised?

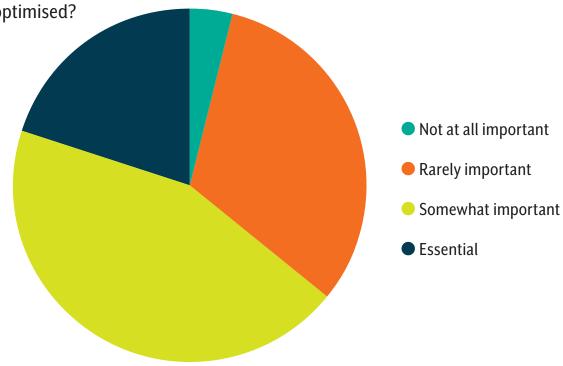


Figure ❷ Which structures require checking?

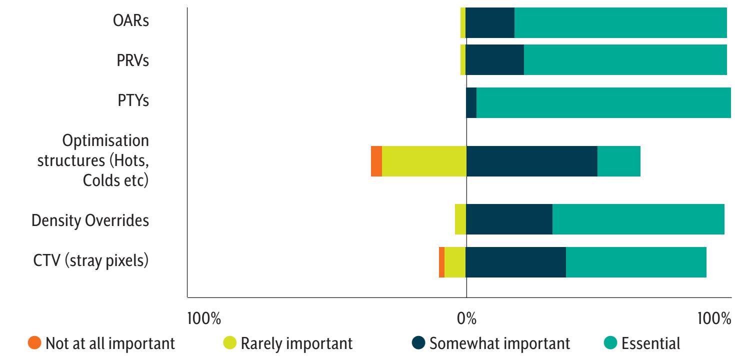


Figure ❸ When checking whether a plan is optimised, how important is it to review the following?

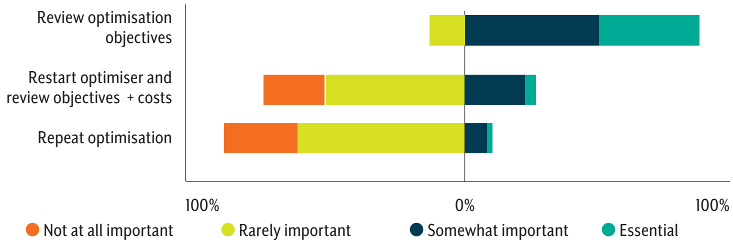
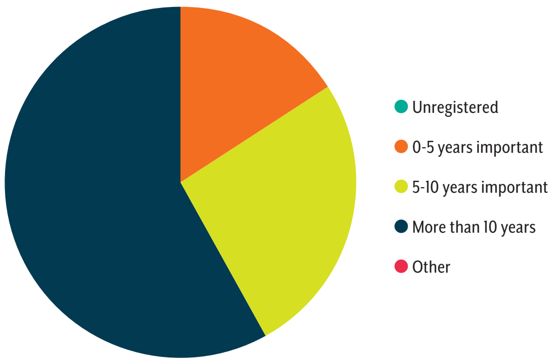


Figure ❹ How many years post-registration are you?



The process of optimisation

We also asked how people decided if a plan was optimised. The vast majority would review optimiser objectives. However, the majority would not then restart the optimiser to review the costs assigned to objectives ❸.

This is interesting since potential improvements aren't always obvious when looking at the static optimiser. My centre found examples where meaningful improvements were only apparent if we repeated the optimisation. Although doing this for all plans is a significant undertaking.

To send back or not send back

The most valuable question for us was: If you notice that the plan could be improved, how do you decide if it should be sent back to the planner?

Clinical significance

A total of 20 responses mentioned the clinical significance of improvements. This was the most common phrase mentioned. But what is clinically significant? Very few responders mentioned discussing the plan with the oncologist. Is a Clinical Scientist making a judgement call on clinical acceptability? Even when the plan is not meeting protocol dose constraints?

A smaller number of responses (5) volunteered dose thresholds for clinical significance, with some variability. Is a 1Gy OAR improvement significant, or a 5Gy improvement? Is a 1% target coverage improvement significant or 5%? Each of these was offered.

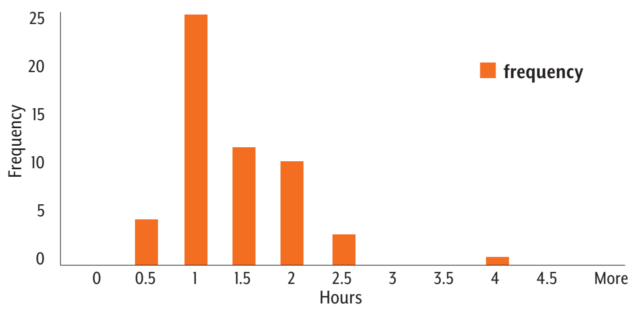
A total of 14 responses alluded to clinical constraints. If a plan was failing to meet a constraint and could be made to pass, then this would provide some support for rejection.

A handful (7) mentioned that they would discuss the plan with the planner. To quote

"FEEDBACK ON A PLAN CAN BE GIVEN INFORMALLY, SHORT OF REJECTING THE PLAN

Figure ❺ Is H&N plan checking a significant part of your weekly workload?

Figure ❻ How long does it take to check a head and neck plan on average?



one response: "Essential to know if they tried something that you think is missing."

Timing and re-optimisation

Several more practical comments were made about the decision process:

- 19 responses mentioned that time constraints would affect their decision. They would be reluctant to reject a plan if it would delay a patient.
- 8 responses mentioned that they would perform a repeat optimisation themselves in order to demonstrate that a plan could be improved.

Interestingly, there was no overlap between the 19 who mentioned time pressures, and the 8 who re-optimised.

Discussion and feedback

A number of comments (3) mentioned the experience of the checker as a significant factor in deciding if a plan was acceptable. It's often a "judgement call".

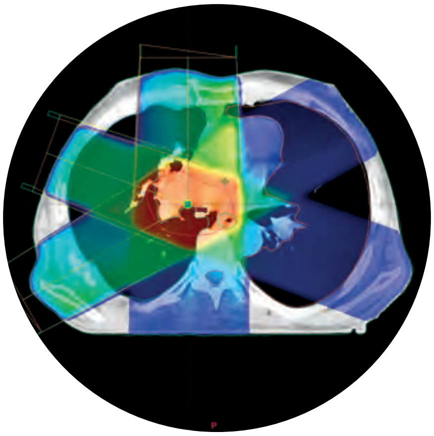
A number of responses also commented that feedback on a plan can be given informally, short of rejecting the plan. This can be especially useful for newly trained planners who benefit from feedback.

The responders

As part of the survey we asked for some information about the responders. How many years post-registration were they ❹, and whether they do a lot of checking ❺.

The majority of responders were >10 years post-registration. Assuming most scientists attain registration in their twenties, this is consistent with recent IPEM RT Workforce profiles, which suggest that 50% of the profession are aged over 40.

The majority of responders said that H&N



checking was a part of their routine work. This may include scientists who rotate into plan checking as a fulltime job, or more senior scientists who pick up a check now and then to maintain proficiency.

There wasn't a significant correlation between either experience or workload, and the qualitative answers given.

The responding centres

We also asked who actually checked the plans. At most centres (59%) only Clinical Scientists would check H&N plans. Some centres (6%) restricted H&N checking to Medical Physics Experts, however this tended to be centres with a lower throughput. At the remaining 35% of centres H&N checking was a dosimetrist task.

We also asked how long plans take to check ❻. The mean result was 1.2 hours, with only one centre reporting >3 hours. My centre had recently audited H&N plan checking times by analysing paperless activity records. This data is inherently noisy, but suggested that we spent considerably more than 1.2 hours on H&N checking. It might be that we're an outlier, or it might be that centres under-estimate how long checks actually take.

Finally, we provided a space for responders to make additional comments. There was plenty of variation here – so much that some responses contradicted others:

- "Plans should not be returned when they meet all tolerances but the checker feels 'they could do better'."
- "Ideally always return to planner but if limited time and clinician has approved the plan I may approve plan for treatment and return to planner for an attempt at plan approval within the 1st few."

The conclusion

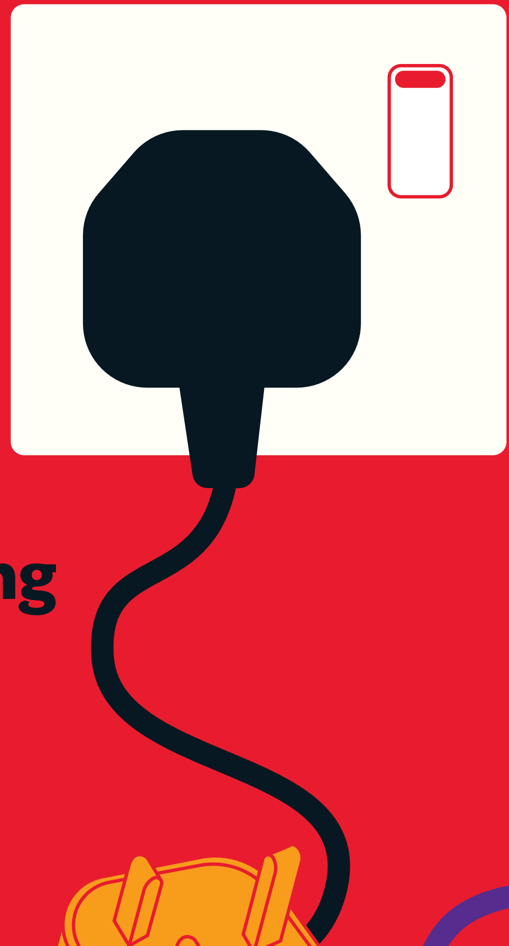
So what did I learn? Firstly, be wary of putting free-text response fields in surveys, since they're a pain to analyse.

More importantly: There's a range of opinion in the UK profession around acceptability and how that aligns with improvability. Clinical significance is an important factor, but there isn't an objective threshold for this. Plan checking and rejection cannot be decided in a vacuum – it may consider time and resource pressures.

On many of these points, there is space for guidance from professional bodies. ◘

__Russell Dawson__ is a Senior Clinical Scientist at The Clatterbridge Cancer Centre NHS Foundation Trust

WHICH FUSE TO USE?



Electrical safety and testing of medical equipment

Consultant Clinical Engineer **Justin McCarthy** looks at a common dilemma in relation to a mains plug fitted to a detachable or non-detachable mains lead.

A question was raised by a delegate to a recent one-day course on electrical safety and testing of medical equipment: "What rating of fuse should be used in the 13 A plug on a detachable mains lead?" It is a reasonable question that I will explore below.

Discussion

In a large hospital, there are probably many hundreds of detachable mains leads available for use. In practice, it is impossible to keep a particular lead with a specific item of equipment. This poses the problem of how best to manage and periodically test these mains leads.

The majority of these detachable mains leads are fitted with a BS 1363 or a BS 1363/A plug at one end, and the very common type C13 ❶ mains connector, conforming to relevant parts of IEC 60320-1, at the other end.

The mains connector plugs into the type C14 ❷ appliance inlet on the equipment. The C13/C14 appliance coupler combination is rated at 10 A. This type of detachable mains lead must be wired with three core cable.

The question is, what rating BS 1362 plug-top fuse should be fitted in the BS 1363 UK mains plug to detachable mains leads with type C13 mains connector? This raises the question of the purpose of the plug-top fuse.

An internet search for possible suppliers of detachable leads as described, indicates that there is considerable variation in both cable size and fuse rating of available products, ranging from 0.5 mm² cable with 3 A fuse to 1.0 mm² cable with a 13 A fuse. Given the impossibility of keeping

DEFINITIONS

The common UK terms used in this paper are given below. The equivalent defined terms used in IEC 60601-1:2005+AMD1:2012 +AMD2:2020 are given in capitals and the definitions from that standard are used or adapted.

Mains lead (POWER SUPPLY CORD): Flexible mains lead, fixed to or assembled with electrical equipment for connection to supply mains.

Detachable mains lead (DETACHABLE POWER SUPPLY CORD): Flexible mains lead intended to be connected to electrical equipment by means of a suitable appliance coupler for mains supply purposes.

Appliance coupler (APPLIANCE COUPLER): Means enabling the connection of a flexible mains lead to electrical equipment without the use of a tool, consisting of two parts: a mains connector and an appliance inlet.

Mains connector (MAINS CONNECTOR): Part of an appliance coupler integral with or intended to be attached to a flexible mains lead that is intended to be connected to the supply mains.

NOTE: A mains connector is intended to be inserted into the appliance inlet of electrical equipment.

Appliance inlet (APPLIANCE INLET): Part of an appliance coupler either integrated in or fixed to electrical equipment for mains supply purposes.

Mains plug (MAINS PLUG): Part, integral with or intended to be attached to a mains lead of electrical equipment, to be inserted into a mains socket-outlet.

NOTE 1: In the UK, often referred to as a "13 A plug" or a "square pin plug". Sometimes called a "plug-top", often in the context of reference to the integral "plug-top fuse".

NOTE 2: UK plugs, sockets and wiring systems are used in other countries, including in Ireland.

Plug-top fuse: The BS 1362 fuse that must be fitted into a BS 1363 UK mains plug.

Medical electrical equipment (MEE): Equipment meeting the requirements of relevant parts of the IEC 60601 suite of standards, in particular the general standard IEC 60601-1.

> **"WHAT RATING OF FUSE SHOULD BE USED IN THE 13 A PLUG ON A DETACHABLE MAINS LEAD?**

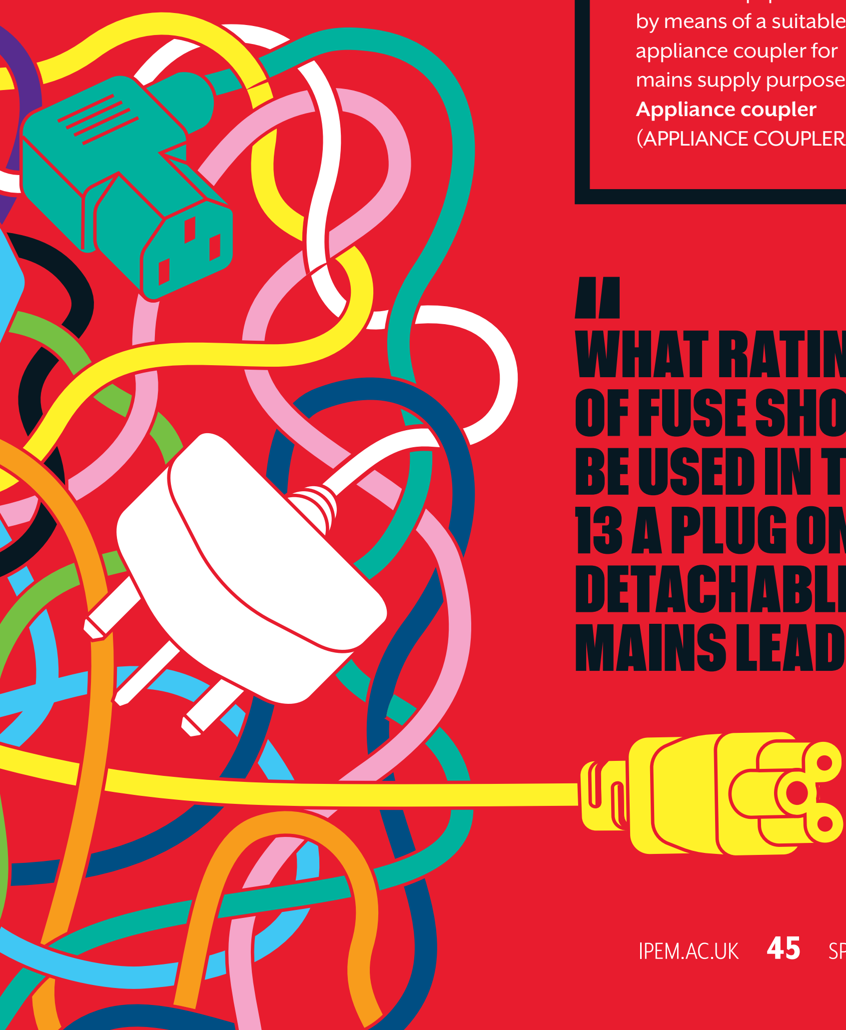


IMAGE: IKON/ HARRY HAYSOM

detachable mains leads with individual items of medical electrical equipment, there needs to be some standardisation of the leads.

The need for a plug-top fuse arises because, in accordance with BS 7671 (The Wiring Regulations), the installed supply circuit, if a ring circuit (usually wired with 2.5 mm^2 twin and CPC cable) is protected by a 32 A circuit breaker, or by a 20 A breaker if wired as a radial circuit with 2.5 mm^2 twin and CPC cable. Damage to a flexible mains cable, such as might occur if run-over with a patient bed could, without the plug-top fuse, cause a severe electrical fault and take out the whole supply circuit, affecting many other items of plugged in equipment.

BS 1362 fuses are available in 1, 2, 3, 5, 7, 10 and 13 A ratings. The BS 1362 standard only specifies the detailed characteristics of the 3 A and 13 A types.

Unlike in domestic premises, many supply circuits in healthcare premises are radial circuits, protected by a 20 A circuit breaker or a 32 A beaker if wired in 4 mm^2 cable. Looking at the characteristics of the BS 1362 13 A fuse, serious damage to a detachable mains lead fitted with a 13 A fuse might trip a 20 A breaker before the plug-top fuse blows (circuit breakers operate much faster than fuses). This would take out the supply circuit, to which other equipment may be connected. This would be very unlikely if a 10 A fuse is fitted to the plug-top, and this is inline with the 10 A rating of the C13 mains connector.

Medical electrical equipment (MEE) must meet relevant parts of IEC 60601 suite of standards. There is a requirement in the general standard, IEC 60601-1, for the mains supply to MEE to be internally fused within the equipment. Thus, internal equipment faults are not relying on the plug-top fuse to protect them.

Therefore, the sensible policy would be to arrange for all detachable mains leads that are fitted with C13 mains connector to be wired with minimally 1.0 mm^2 cable, and fitted with a 10 A fuse. They should be periodically tested by visual inspection and an earth continuity test. For the purpose of testing the earth continuity end-to-end of the detachable mains lead, a Type C14 connector shown above (meeting IEC 60320-2-2) can be made up with only an earth connection accessible. Earth continuity should be less than or equal to 0.1 Ω.

Minimise risks

When brand new, each detachable lead should be checked for polarity and for insulation. Polarity will not alter from the "as new" situation. Insulation is only likely to be compromised by damage which, in-service, will be checked by visual examination, and a tactile examination for severe kinks along its length. Any lead tested as part of an equipment test will be subjected to an in-service insulation test. It is not a practical possibility to put each individual detachable mains lead on the inventory as an identifiable item, but each should be labelled with a "Next test due" date.

If the suggested procedure is followed, then the risks from using any available detachable mains lead are minimised. All are to the same specification.

A 10 A fuse in the plug-top would allow for any item of equipment up to 2.4 kW to be supplied. Higher rated equipment should not be run off a C13 mains connector.

An alternative, larger C19/C20 appliance coupler combination ❸, rated at 16 A is/should be used for higher rated equipment. Such detachable mains leads should be wired with 1.5 mm^2 cable, and the plug-top fused at 13 A. They are much more likely to remain with the equipment they are designed for, but similar routine checks should be carried out on any not associated with a particular item of equipment.

Other types of main connectors

Two other types of mains connectors on detachable mains leads are in fairly common use, particularly with IT-type equipment.

Low power Class II equipment often uses the C7 ❹ "figure of eight" mains connector shown in the boxout.

The C5 ❺ mains "clover leaf connectors" shown left, are often found on laptop switched-mode power supplies or other low power Class I equipment.

Both C7 and C5 mains connectors are rated in the IEC 60320-1 Standard at 2.5 A and 250 V. United States version may carry

THE CONNECTORS

❶ C13 mains connector

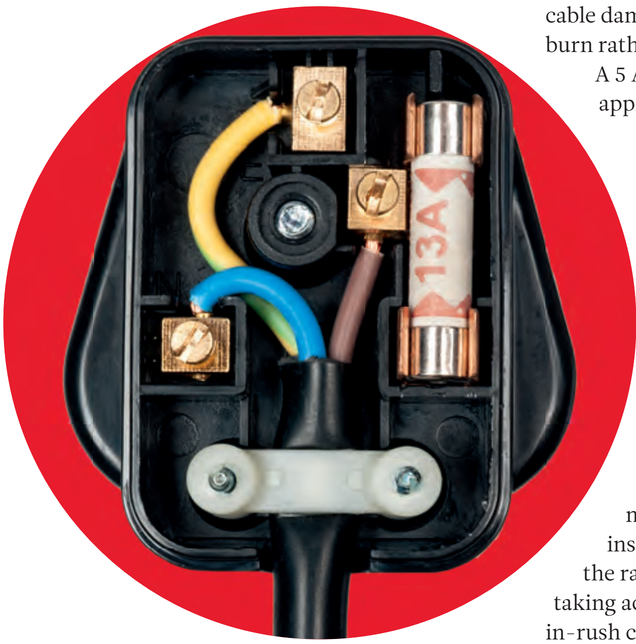
❷ Type C14 plug connector

❸ C19/C20 appliance coupler

❹ Type C7 mains connector

❺ Type C5 mains connector

"THE DANGER IS THAT SERIOUS CABLE DAMAGE COULD CAUSE THE CABLE TO BURN RATHER THAN THE FUSE TO BLOW QUICKLY



a higher rating marking. The standard does not allow rewireable versions.

Mains leads using these are likely to use 0.75 mm^2 cable, but some may be only 0.5 mm^2. These cables should be fused in the plug-top with a 3 A, BS 1362 fuse.

Routine visual inspection, and for the C5 type, earth conductor continuity checks, and labelling are all required.

Non-detachable mains leads

The basic principle that the plug-top fuse is there to protect the supply circuit in the case of a mains cable fault or damage is still applicable. However, some items of MEE are fitted with lighter duty, fixed mains cables.

The danger of having a 13 A plug-top fuse supplying a equipment wired with 0.75 mm^2 cable (rated at 6 A) is that serious cable damage could cause the cable to burn rather than the fuse to blow quickly.

A 5 A plug-top fuse would be appropriate.

Other MEE with internal fuses greater than 6 A, and wired with non-detachable mains cables should have 1.0 mm^2 cable. It is acceptable to use a 10 A plug-top fuse, but there is no risk involved in using an appropriate lower rating.

Non-MEE with non-detachable mains leads and without internal fuses should be fitted with a plug-top fuse either based on the manufacture's installation instructions or appropriate to the rating of the equipment, but taking account of any likely start-up in-rush current such as occurs with motor-driven equipment.

For example, desk lamps, wired with 0.75 mm^2 or lighter cable, may reasonably be fused at 1 A but a vacuum cleaner or floor polisher will need a 10 A or 13 A fuse.

Summary proposals

For MEE:

- Detachable mains leads fitted with BS 1363 UK plugs and C13 mains connectors should be wired with minimally 1.0 mm^2 three-core cable, and fused at 10 A. They should be periodically physically inspected and tested for protective earth conductor resistance $\leq 0.1\Omega$ and labelled with a "next test due" date.
  - Detachable mains leads wired with 0.75 mm^2 cable and fitted with C13 mains connector should not be used or available.
  - Detachable mains leads fitted with a C19 mains connector should be wired with 1.5 mm^2 cable and the plug-top fused at 13 A and tested as above.
- Detachable mains leads fitted with BS 1363 plugs and C7 or C5 mains connectors should be fused with a 3 A plug-top fuse.
- For non-detachable mains leads, BS 1363 plugs fitted to 0.75 mm^2 cable should be fused in the plug-top with a 5 A fuse or lower, as recommended by the manufacturer.
- For non-detachable mains leads, BS 1363 UK plugs fitted to 1.0 mm^2 cable may be fused in the plug-top with a 10 A fuse, or lower as recommended by the manufacturer, but should not be fused at 13 A.

For non-MEE:

- As above, to maintain compatibility whatever the usage, detachable mains leads fitted with BS 1363 UK plugs and C13 mains connectors should be wired with minimally 1.0 mm^2 three-core cable, and fused at 10 A.
- Similarly, detachable mains leads fitted with BS 1363 plugs and C7 or C5 mains connectors should be fused with a 3 A plug-top fuse.
- BS 1363 UK plugs fitted to 0.5 mm^2 non-detachable mains leads should be fused in the plug-top with a fuse not exceeding 3 A. A lower value may be appropriate for low power equipment.
- Non-detachable mains leads with BS 1363 UK plugs fitted to 0.75 mm^2 cable should be fused in the plug-top with a fuse not exceeding 5 A. A lower value may be appropriate for low power equipment.
- Non-detachable mains leads with BS 1363 UK plugs fitted to 1.0 mm^2 cable should be fused in the plug-top with a fuse appropriate to the power consumption of the equipment, but taking account of any likely inrush current.

__Justin McCarthy__ is an IPEM Fellow and Consultant Clinical Engineer at Clin Eng Consulting Ltd. He is interested in comments and feedback on these suggestions via the Clinical Engineering Community of Interest on the IPEM website.

REGISTRATION OF MEDICAL PHYSICS EXPERTS IN EUROPE

Brenda Byrne and **Veronica Rossetti**, Chairs at the European Federation of Organisations for Medical Physics (EFOMP), explain its role in registration of Medical Physics Experts in Europe.

Above: The EFOMP Governing committee at ECMP 2022 in Dublin.

The European Federation of Organisations for Medical Physics (EFOMP) was founded in May 1980 in London to serve as an umbrella organisation for all national member organisations (NMOs). The current membership covers 37 NMOs, which together represent more than 9200 medical physicists and clinical engineers working in the field of medical physics. The UK was one of the founding members of EFOMP and IPEM members continue to play a pivotal role in the organisation to this day.

Medical Physics Experts

Medical physics is a health profession where physical principles are applied in medicine for the benefit of patients and staff, both concerning efficacy and efficiency of diagnosis and treatment. The physical principles include optics, mechanics, electricity and magnetism and, last but not least, nuclear physics. Nuclear physics in medical physics is mostly directed toward application of ionising radiation in medicine for the benefits of patients. The key role of the Medical Physics Expert (MPE) in safe and effective use of ionising radiation in medicine is widely recognised in European reference documents, such as the EU Council Directive 2013/59/EURATOM (2014), and European Commission Radiation Protection No. 174, European Guidelines on Medical Physics Expert (2014). The role of MPEs in non-ionising radiation is also developing significantly over the years especially in the areas of MRI and lasers. EFOMP has published some policy statements on these topics (see the "policy statements" section of EFOMP's website).

Enhancing education and training

One of EFOMPs main aims is proposing and developing guidelines for education, training, continuous professional development, registration and certification programmes. EFOMP's European School for Medical Physics Experts (ESMPE) is our starting point for enhancing education and training programmes for medical physics in Europe. This objective is bolstered by two other important pillars, namely the biennial European Congress of Medical Physics (ECMP) and EFOMP's official journal, *Physica Medica: European Journal of*

Medical Physics. ESMPE organises medical physics education and training events specifically targeted to medical physicists who are already Medical Physics Experts or would like to achieve Medical Physics Expert (MPE) status. The schools are accredited by an independent body (the European Board of Accreditation for Medical Physics) to ensure that they are at the required educational level – Level 8 of the European Qualifications Framework. The main topics of ESMPE School editions are related to ionising and non-ionising radiation applied in medicine as well as specific topics such as statistics, AI and informatics. Our EFOMP website hosts our e-learning platform, which allows access to all our past ESMPE course content through Individual Associate Membership for a low annual fee. The development and enhancement of this platform are key strategic objectives for EFOMP.

Common query

One of the most common queries to the Professional Matters Committee is regarding the possibility to get an MPE certificate in one European country if an MPE certificate was already obtained in another European country. Unfortunately, there is no automatic recognition of MPE certification between European countries since the role of MPE is not one of the professions recognised by the European Union (EU) in Directive 2005/36/EC, which enables the free movement of professionals such as doctors or nurses within the EU. EFOMP wants to change that but in order to do this we need to ensure harmonisation of education and training of MPEs across Europe. The first step to ensure harmonisation is the approval of the national registration schemes (NRS) for MPEs in each NMO. EFOMP hopes that by gaining such recognition it can also be extended to European economic areas and other non EU countries, such as the UK, which accounts for a quarter of our 37 NMOs. Now is the opportunity for our profession to take our future in our own hands and seek recognition from the EU and European countries outside the EU as a recognised profession, but we can only do this with the support of our NMOs. EFOMP believes that such mobility will help with issues in tackling the oncological and radiological workforce shortages, harmonise improved training standards, improve access to quality physics-driven health care and new technologies, such as particle therapies and molecular radiotherapy, as well as economic benefits.

"NOW IS THE OPPORTUNITY FOR OUR PROFESSION TO TAKE OUR FUTURE IN OUR OWN HANDS

IMAGES: ISTOCK

EFOMP has a long history of approval of NRS for MPEs dating back to 1990s. In 2018, following the publication of European Guidelines on Medical Physics Expert (RP174) and the EU Council Directive 2013/59/Euratom, EFOMP introduced a new procedure to approve NRS for NMOs to ensure the education and training of MPEs included the knowledge, skills and competencies as outlined in RP174. NMOs can access the available application form and procedure for NRS approval on the EFOMP website.

Improve and coordinate

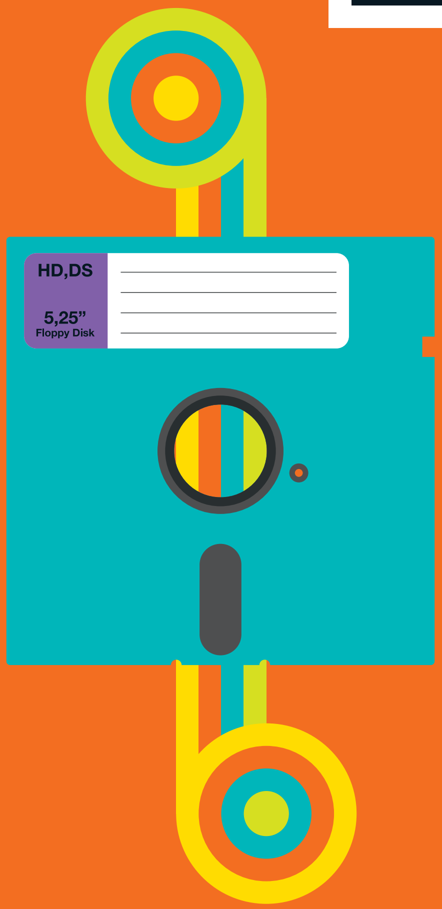
From its inception, EFOMP has pursued a policy to improve and coordinate education and training of medical physicists across all its participating European countries. Several EFOMP policy statements on education and training have been published and surveys have been held to get an overview of the actual situation. A paper published by EFOMP in 2021, titled "Education, training and registration of Medical Physics Experts across Europe", showed that 22 NMOs have a system for education, training and registration of MPEs in place and therefore should be eligible to apply for NRS approval. With the implementation of EU Council Directive 2013/59/EURATOM into national laws in each NMO, we expect the number of NMOs with an NRS to increase. As of January 2024, 11 NMOs had applied for approval of their NRS and all of them were approved after a thorough evaluation of the underlying documents. We are strongly encouraging those NMOs with an NRS in place to apply for approval of their NRS by EFOMP. We hope that we can work with IPEM to get approval for the UK scheme which has always been regarded as a flagship for other schemes in Europe.

NRS approval by EFOMP does not guarantee that MPE registrations are accepted by other NMOs, but still it is an important step forward. EFOMP is currently preparing an application to seek approval from the EU and other nations to recognise and protect the title of MPE and establish MPEs as a profession recognised by EU and other nations in Directive 2005/36/EC and other Basic Safety Standard legislation. This can only benefit our profession by allowing MPEs to transfer their qualifications and skills between NMOs and prevent unqualified personnel from using the title MPE.

***Brenda Byrne** is the EEFOMP Secretary General and Past Chair Professional Matters Committee.*
***Dr Veronica Rossetti** is the EFOMP Chair of the Education and Training Committee. For more information on EFOMP, visit efomp.org or follow on social media channels.*

WE WANTED TO MAKE A DIFFERENCE

Professor Andy Beavis, Head of Medical Physics for the Hull University Teaching Hospitals NHS Trust, Professor at the Hull York Medical School, Professor at University College London and CSO and Founder of Vertual Ltd, shares a poem.



Bentley and Milan taught us to compute
dose with simple PCs.
We used plaster of Paris bandages to trace
the shape of the body,
X-ray films on boxes of light, to find distances
between OARs and hidden tumour.
We limited the dose and statistical control,
fearing collateral damage.
We called this two Dimensional Radiotherapy.
We wanted to do more...

Godfrey – and his students – gave us the
CT scanner.
On an 8-inch floppy disk, Andy drove to
collect the image of the week for the
golden ticket winner. That one, central
prostate slice, was all we could afford.
We filled the body contour with water and
used our four-field box to great precision,
or so we believed.
We called this two and a half Dimensional
Radiotherapy.
We wanted to do more...

Sherouse and Kalet pioneered in three
dimensions, Mackie wrote his thesis; we
said to the beams "don't be square –
daddio!"
Helax produced their commercial system,
but they expanded too rapidly and
floated away.
Computer memory grew and grew and
the networks brought us Moore and Moore
images.
We called this three Dimensional
Conformal Radiotherapy.
We wanted to do more...

Brahme and Webb showed us how to plan
backwards,with psychedelic results.
Convery and Bortfield modulated and
taught us their dance sequences.
Carol had his vision and his Carpenter
Dawson MiMic'd the dream.
Baylor began the long strange trip,
MSKCC followed and we got Truckin'.
We called this three Dimensional Intensity
Modulated Radiotherapy.
We wanted to do more...

Mackie, Holmes and Reckwerdt
understood the geometric limitations and
Guided us all. The rule book was torn up,
thrown away and rewritten. Marcel wrote
down his formula and challenged us to
embrace our uncertainties. We tightened
our margins and focused on Target to spare
our sensitivities.
We called this three Dimensional Image
Guided Intensity Modulated Radiotherapy.
We wanted to do more...

Professor Sir Mike Richards called the UK to
action, threw down his challenge to all. Tim
Cooper rallied his Urban Guerillas, and we
camped out near Victoria. We gathered
data, we lobbied hard, we wrote to David
Cameron to tell him what we could do.
Ministers promised a few quid.
Sir Mike said: "Please sir, can we
have more?"
We called this the Radiotherapy
Innovation fund.
We wanted to do more...

Every Oncologist, Radiographer,
Dosimetrist and Physicist was trained, so
they couldn't say "we don't know how."
Richards and Cooper played Santa, the
Guerillas helped departments open their
presents and read the instructions.
We met Sir Mike's challenge and 24% of our
patients got IMRT.
We called this World Class Radiotherapy
and we did it in the UK.
We always wanted to do more...

We need to refresh technology for today's
Merry Pranksters to take us Furthur.
Tumour engineering drugs will sensitise the
resistant and prove their va£ue.
The Learning Machines will find knowledge
we don't yet know we need, at speeds we
can't believe.
Well-trained, motivated staff will
push the possibilities beyond where
we ever imagined.
Please, politicians, please, don't let it spiral
down through the night and f-f-f-f-fade
away.
We still want to do more...

INTERNATIONAL CONFERENCE ON MEDICAL PHYSICS

Mumbai, India

Jen Cannon, IPEM's Professional Knowledge and Innovation Manager and a Health and Care Professions Council-registered Clinical Scientist, discusses IPEM's attendance at the International Conference on Medical Physics (ICMP) in Mumbai, India in December 2023.

ICMP is the three-yearly conference organised by the International Organisation of Medical Physics (IOMP). The IOMP represents over 30,000 medical physicists worldwide and is formed of 90 national member organisations, of which IPEM is a member through the European Federation of Medical Physics (EFOMP).

My role within IPEM is to lead on and implement the Science Leadership Strategy, and this is achieved through gaining knowledge of the new scientific and professional advancements within the fields of medical physics and clinical engineering. The theme of ICMP 2023 was "Innovations in Radiation Technology and Medical Physics for Better Healthcare", with presentations being delivered by many Indian researchers, in addition to speakers from across the globe, including Australia, the US, Japan and China.

Provoking ideas

I attended a talk from Professor Eva Bezak, Vice President of IOMP and President of the Asia-Oceania Federation of Organisations in Medical Physics (AFOMP), who delivered a session titled "GRID, FLASH and other superheroes of radiation therapy". This discussed the use of spatially fractionated radiotherapy (GRID/LATTICE therapy), which splits an open radiation field into a series of small, high-dose pencil beams, resulting in a highly non-uniform dose distribution. This has significantly beneficial effects on debulking large and radio-resistant tumours.

Professor Bezak also discussed inequalities in healthcare, with a focus on hypofractionated radiotherapy treatments. Hypofractionated treatments are a radiotherapy treatment approach that shortens the overall duration of a radiotherapy course by delivering fewer

Figure 1 The IPEM team at the International Conference on Medical Physics in Mumbai

treatments overall but a higher dose of radiation per treatment. Professor Bezak emphasised that hypofractionation is the most effective way of reducing the carbon impact of radiotherapy treatments, however, the infrastructure for radical hypofractionated radiotherapy treatments is not available in many low- and middle-income countries (LMICs) and therefore there are limited actions that can be taken in these countries to minimise carbon emissions in healthcare.

This talk was fascinating and provoked many ideas around how IPEM can help support the development and accessibility of emerging techniques, both in the UK and internationally, which will greatly aid the development of IPEM's Science Leadership activities.

Artificial intelligence

I also attended sessions discussing the implementation of artificial intelligence (AI) in India. In the UK, discussions around AI often involve the equality, diversity and inclusion (EDI) issues relating to training AI datasets. However, from an Indian perspective, the challenges being faced are significantly different. In particular, digital storage solutions are a challenge, and medical physicists in India have developed their own AI algorithms as commercial software isn't feasible to be implemented. This really highlighted to me that there is also an equality and diversity in access to AI platforms, in addition to the EDI concerns around the patient datasets used.

Another fascinating talk was delivered by Dr Parminder Basran, an Associate Research Professor in Medical Oncology at Cornell University. Dr Basran presented his work on developing an online platform called "WORLD of Medical Physics", which collates all open-access and global public resources for medical physics trainees specialising in radiotherapy, with a view to especially help trainees in LMICs access a range of free training resources. I spoke with Dr Basran at length after his talk to see how IPEM can be involved in supporting this initiative, as IPEM has a significant range of publications that could be utilised on this platform.

Meetings and a symposium

We also had an exciting visitor at the IPEM stand – Dr Sudhir Kumar, who has submitted the highest number of papers to IPEM's journal *Physics in Medicine & Biology* (PMB) in all of India. Dr Kumar is a Research Scientist at the Bhabha Atomic Research Centre, and it was very exciting to meet someone who was so passionate about our journals.

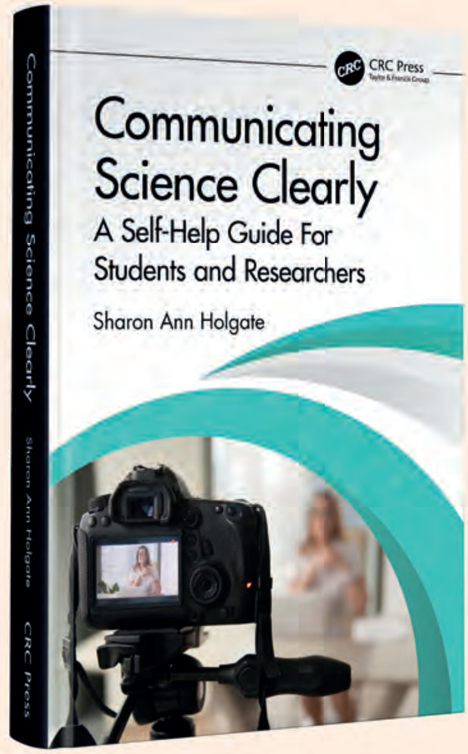
Throughout the conference, we engaged with a range of industry sponsors, including Panacea, PTW and Elekta, and engaged in many thoughtful discussions with other professional bodies, such as the American Association of Medical Physicists (AAPM).

We also hosted an IPEM symposium titled "Growing careers in Medical Physics", with talks delivered by Dr Jemimah Eve, IPEM's Director of Policy and Impact, Dr Claire-Louise Chapple, IPEM's Vice President International and Dr Manju Sharma, member of the AAPM Global Research and Scientific Innovation Committee.

The symposium showcased routes to become a medical physicist in the UK and internationally and shared advice on how international delegates can develop their careers by participating in professional development and academic opportunities. This was an excellent platform to enable conversations that allowed IPEM to understand the needs of international members, and to provide advice for members from abroad who are seeking to work in the UK. Following this session, many delegates came to the IPEM stand to discuss this more with staff, with many queries relating to HCPC registration in the UK and how this differs to other countries.

For IPEM to have this hands-on approach with international delegates was invaluable, and we have gained many significant insights and connections from attending ICMP.

"FOR IPEM TO HAVE THIS HANDS-ON APPROACH WITH INTERNATIONAL DELEGATES WAS INVALUABLE



BOOK PITCH

Communicating Science Clearly:

A Self-Help Guide For Students and Researchers

IPEM member **Dr Sharon Ann Holgate** outlines the idea behind and the content within her new book.

As a child I had several operations and many investigative procedures at Great Ormond Street Hospital for Children. In each case, the main thing that reduced my anxiety was medical staff explaining to me what was going on and how the various machines worked. I can still vividly recall a radiographer who, on learning I was interested in science, talked me through the images from my CT brain scan.

The 12-year-old me was given a wonderful introduction to the concept of image slices by likening the shape of my brain in the various cross-sections to that of cooked eggs. We went from boiled to poached to fried, then back through the menu again as we exited the other side of my cranium. I was left in awe of this incredible technology. But as well as piquing my scientific curiosity, the absorbing explanation pitched at exactly the right level calmed me down after what had been a scary, claustrophobic and uncomfortable experience.

Tailoring science to your audience – whether that is an individual patient, the wider public, or a lecture hall full of professionals – and the use of analogies are just two of the topics covered in my latest book *Communicating Science Clearly*. I had the idea for this book in 2021 after we'd exited from the third of the UK's COVID lockdowns. Not surprisingly communication had been on my mind, from public health messaging to using remote technologies – the latter of which has a dedicated chapter in my book. I'd also been reflecting on the wealth of advice colleagues and mentors had shared over the 25 years I'd been a science writer and broadcaster, and on how much I'd enjoyed recent duties as a guest educator on the Science Communications module for fourth-year MSci and MSc physics students at King's College London.

" CONCISE CHAPTERS WILL PROVE IDEAL FOR THE TIME-POOR

It seemed the right moment to pass on the expertise I'd amassed in a book that readers can dip in and out of when needed. I am hoping that the concise chapters will prove ideal for the time-poor – such as anyone being interviewed on radio or TV at short notice. Forward planning is also extensively discussed, not least in the "Troubleshooting" chapter which gives tips on how to deal with issues such as technology failing or stage fright taking over. Other scenarios covered in *Communicating Science Clearly* include reporting to your manager, coping with job interviews, talking to patients, writing articles for the popular press, creating social media posts and website content, and presenting talks or posters at scientific conferences. Alongside my thoughts is advice from other seasoned communicators including a radio producer, a TV presenter, actors and entertainers, a PR specialist, a medical physicist and a psychologist.

While my book aims to help readers as rapidly as possible, learning to communicate scientific concepts well requires practice and dedication. But the next time you share complex information with patients or colleagues remember that – as my story shows – good science communication can have incredibly positive impacts and be remembered for many years to come.

***Communicating Science Clearly: A Self-Help Guide For Students and Researchers** is published by CRC Press (£34.99)*

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