ipem.ac.uk
Volume 32 | Issue 2 | SUMMER 2022

IPEM
Institute of Physics and Engineering in Medicine

SCOPE

From reusing PPE to ditching disposable cups and promoting video consultations

ENVIRONMENTAL SUSTAINABILITY

SOFTWARE
The scope and flexibility of Redmine for project management

INCLUSIVITY
Equality, diversity and inclusion in medical physics

RADIOTHERAPY
Source-to-surface change in modern lung cancer radiotherapy

IPEM WEBSITE
A look at the new modern, responsive IPEM platform

CHAIR OF IPEM SCOPE EDITORIAL ADVISORY BOARD

Fantastic insights

Usman Lula outlines the content in the latest issue of *Scope*, including sustainability, equality, diversity and inclusion and open-source software.

Welcome all to another bumper issue of *Scope*! Thank you to all those who have contributed – we endeavour to push the bar for quality and variety of relevant content.

One of the most exciting features we have in this issue is a piece on environmental sustainability, kindly supplied by Laura Perry. This is a follow up to the debate we had on this topic in the winter 2021 issue around its impact on healthcare and science. In theory, discussing such topics of importance is a shared responsibility and, to an extent, we have perhaps fulfilled this by and large. More importantly, what will now pay us dividends for the efforts we make is how this is translated, introduced, maintained and improved in our practical day-to-day working lives. How do we start such a project in the first place? How do we convince our colleagues from cross disciplines that net-zero aims and a local green plan should be on our agenda? How could we get staff at every level to contribute to the cause and provide the necessary support and training? To answer these questions, Laura provides a fantastic insight into her own experiences, proving that anything is possible if you put your mind to it.

> How do we convince our colleagues from cross disciplines that net-zero aims and a local green plan should be on our regular agenda?

You will also find in this issue Erin Donovan exploring equality, diversity and inclusion and associated with this, promoting smaller positive actions. Although these topics are covered in mandatory training, there are also legal implications surrounding these. On the more practical day-to-day aspect, it then is useful to know how these areas play a role. Erin has written an awesome piece that will get you thinking about how we communicate and the nature of the language used with our colleagues, patients and so forth.

For those who are looking to maximize the use of open-source software (see the "fault finding" feature in the spring 2022 issue), we have a fantastic follow-up feature by Robert Ross on the extended use of Redmine software – a web-based project management and issue tracking tool. Only this time, the extended use covers searchable Wikis, tracking the status of treatment units, tracking progress of QA, archival record keeping or, in short, a single-stop resource. Read on to find out more.

Aloha!

Usman Lula

Usman Lula
Chair of IPEM *Scope* EAB

IPEM WEBSITE

A fluid interface

Anyone regularly visiting ipem.ac.uk will find that there is a brand new website, which went live in March. There is a really nice fluid interface, with access to everything using menus at the top. There is a lot more content on the home page, split into neat sections (e.g. featured events, mission, resources, events, communities of interest), and a great search facility (e.g. in the latest news section). To find out more, we have a feature just on this.

If you would like to contribute to *Scope*, please get in touch with me (usman.lula@uhb.nhs.uk), our Editor Rob (rob.dabrowski@redactive.co.uk) or any of the *Scope* Editorial Advisory Board members. We would be keen to support you to write your first feature and any requirements (if that is the case) or discuss your proposal for submission. Don't forget – your submission counts towards your CPD. If you need an incentive, your feature could be chosen for the annual Keith Boddy award – that's £250 in your pocket plus a certificate!

IPEM
Institute of Physics and Engineering in Medicine

Scope is the quarterly magazine of the Institute of Physics and Engineering in Medicine

IPEM Fairmount House, 230 Tadcaster Road, York, YO24 1ES
T: **01904 610821** | F: **01904 612279**
office@ipem.ac.uk | **ipem.ac.uk** |

Chair of IPEM *Scope* Editorial Advisory Board: **Usman I. Lula**
Principal Clinical Scientist, 1st Floor, Radiotherapy, Building, Medical Physics – University, Hospitals Birmingham NHS Foundation Trust, Queen Elizabeth Hospital, Queen Elizabeth Medical Centre, Birmingham, UK B15 2TH
0121 371 5056 | **usman.lula@uhb.nhs.uk**

Commissioning Editor
Ejay Nsugbe

Commissioning Editor
Clara Ferreira

Commissioning Editor
Natasa Solomou

Commissioning Editor: **Usman I. Lula**
0121 371 5056 | **usman.lula@uhb.nhs.uk**

Commissioning Editor: **Dr Paul Doolan**
Medical Physicist, German Oncology Center, 1 Nikis Avenue, 4108 Agios Athanasios, Limassol, Cyprus
00357 2520 8025 | **paul.doolan@goc.com.cy**

Scope is published on behalf of the Institute of Physics and Engineering in Medicine (IPEM) by

Redactive Publishing Ltd
redactive.co.uk

redactive

Publisher: Tiffany van der Sande
tiffany.vandersande@redactive.co.uk | +44 (0)20 7324 2728

Editor: Rob Dabrowski

Lead designer: Glen Wilkins

Picture researcher: Claire Echavarry

Production: Aysha Miah-Edwards
aysha.miah@redactive.co.uk | +44 (0)20 7880 6241

Advertising sales:
scope@redactive.co.uk | +44 (0)20 7880 7556

Scope is published quarterly by the Institute of Physics and Engineering in Medicine but the views expressed are not necessarily the official views of the Institute. Authors instructions and copyright agreement can be found on the IPEM website. Articles should be sent to the appropriate member of the editorial team. By submitting to *Scope*, you agree to transfer copyright to IPEM. We reserve the right to edit your article. The integrity of advertising material cannot be guaranteed.

FEEDBACK
Discuss, debate, share.
mycommunity.ipem.ac.uk/login

WEBSITE
News, events, support.
ipem.ac.uk

ARCHIVES
Back issues of *Scope* online.
ipem.ac.uk/scope

CO

COVER FEATURE

> After 70 uses the gowns are retired from use and recycled or reused in other settings.
>
> – *Principal Nuclear Medicine Physicist Laura Perry* **page 14**

UPFRONT

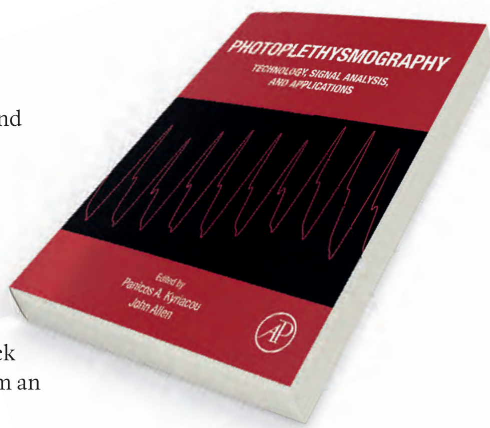
Cover image by
NEIL WEBB

Volume 32 | Issue 2 | Summer 2022

NTENTS

GENERAL

ENDNOTES



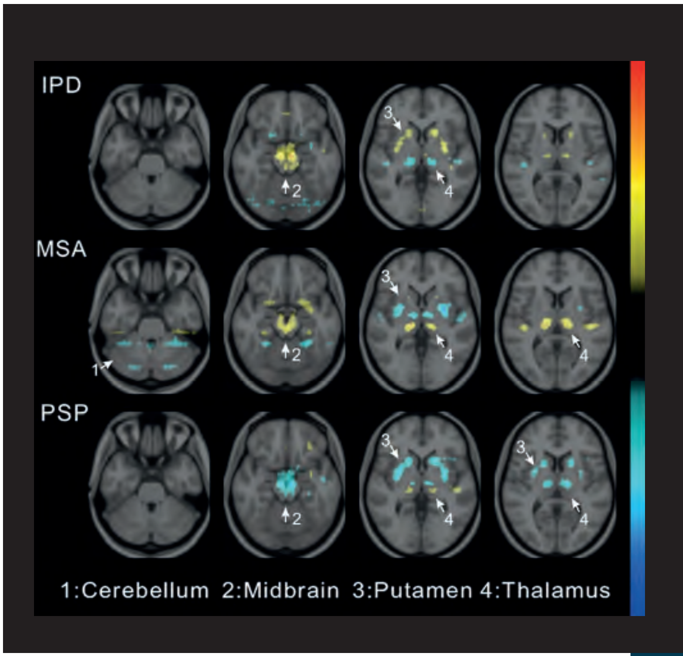
FEEDBACK
Discuss, debate, share
my.community.ipem.ac.uk

WEBSITE
News, events, support
ipem.ac.uk

UPFRONT

MOLECULAR IMAGING

Deep learning for parkinsonian diagnosis



A new deep learning method has been created with the aim of aiding in the diagnosis of parkinsonian diseases.

Using a 3D deep convolutional neural network to extract deep metabolic imaging indices from 18F-FDG PET scans, scientists can effectively differentiate between Parkinson's disease (PD) and other parkinsonian syndromes, such as multiple system atrophy (MSA) and progressive supranuclear palsy (PSP).

According to the Parkinson's Foundation, more than 10 million people worldwide live with the disease.

Accurate diagnosis of PD is often a challenge – particularly in the early stages – as its symptoms overlap considerably with those of other atypical parkinsonian syndromes.

Ping Wu, neuroradiologist at Huashan Hospital, Fudan University in Shanghai, China, said: "Studies show that 20–30% of patients with initial diagnoses of PD were subsequently demonstrated to have MSA or PSP after pathological examination.

"Therefore, the development of accurate indices to differentiate between parkinsonian diseases is of great importance, specifically with regard to determining treatment strategies."

To achieve this objective, researchers built a 3D deep convolutional neural network, known as the Parkinsonism Differential Diagnosis Network (PDD-Net), to automatically identify imaging-related indices that could support the differential diagnosis of parkinsonian diseases.

This work confirms that the emerging AI can extract in-depth information

This deep learning method was used to examine parkinsonian PET imaging from two groups: more than 2100 patients from China and 90 patients from Germany.

"It's important to note the steps that were taken to improve the trustworthiness of the study," said Wu. "We utilised the largest benchmark dataset of parkinsonian patients with FDG PET from Huashan Parkinsonian PET Imaging database in Shanghai, China, and conducted extensive testing on longitudinal data. In addition, we studied the German cohort to include external data representing different ethnicities and examination protocols."

The deep metabolic imaging indices achieved sensitivities of 98.1%, 88.5%, and 84.5%, and specificities of 90.0%, 99.2%, and 97.8% for the diagnosis of PD, MSA, and PSP in the blind test cohort. In the German cohort, they resulted in sensitivities of 94.1%, 82.4%, 82.1%, and specificities of 84.0%, 99.9%, 94.1%, respectively.

"This work confirms that the emerging artificial intelligence can extract in-depth information from molecular imaging to enhance the differentiation of complex physiology," Wu said. "Deep learning technology may help physicians maximise the utility of nuclear medicine imaging in the future."

bit.ly/3KALp8I

FAST FACTS

+10m
People worldwide are estimated to have Parkinson's disease

20–30%
Diagnoses of Parkinson's turn out to be parkinsonian syndromes

+2190
Patients had their PET imaging examined in the research

NEUROLOGY

Machine learning model for traumatic brain injury patients

A prognostic model is the first to use automated brain scans and machine learning to inform outcomes in patients with severe traumatic brain injuries (TBI).

The team from the University of Pittsburgh School of Medicine showed that their advanced machine-learning algorithm can analyse brain scans and relevant clinical data from TBI patients to quickly and accurately predict survival and recovery at six months after the injury.

Co-senior author on the study David Okonkwo said: "Every day, in hospitals across the US, care is withdrawn from patients who would have otherwise returned to independent living.

"The majority of people who survive a critical period in an acute care setting make a meaningful recovery – which further underscores the need to identify patients who are more likely to recover."

It often takes two weeks for TBI patients to emerge from their coma and begin their recoveries—yet severe TBI patients are often taken off life support within the first 72 hours after admission.

The new predictive algorithm, validated across two independent patient cohorts, could be used to screen patients shortly after admission and can improve clinicians' ability to deliver the best care at the right time.

bit.ly/3sdRQrL

MAGNETIC RESONANCE IMAGING

Nano-sensors to pinpoint infectious diseases

Premature babies who develop abnormalities, such as autism and cerebral palsy as teenagers, have subtle differences in brain structure that can be detected on quantitative magnetic resonance imaging (qMRI), according to a new study.

Researchers said the findings show the potential for qMRI, which obtains numerical measurements, to help improve outcomes for the growing numbers of people born preterm.

They used qMRI to assess the brains of adolescents who had been born extremely preterm. The researchers collected data from MRI scanners at 12 different centres on females and males, ages 14 to 16 years.

They compared the qMRI results between atypically versus neurotypically developing adolescents.

The comparison included common MRI parameters, or measurements, like brain volume. It looked at less commonly used parameters too.

Of the 368 adolescents in the study, 252 developed neurotypically, while 116 had atypical development. The atypically developing participants had differences in brain structure visible on qMRI.

bit.ly/39rdQsA

NEWS IN BRIEF

505 days of COVID

The longest known COVID-19 infection was described by UK researchers at this year's European Congress of Clinical Microbiology and Infectious Diseases. The patient tested positive for COVID-19 for 505 days before their death. The previous longest known PCR-confirmed case is thought to be 335 days. The UK study involved nine immunocompromised patients who tested positive for the virus for at least eight weeks. Infections persisted for 73 days, on average, but two patients had persistent infections for more than a year.

bit.ly/39q6qFZ

Long COVID tool

A comprehensive tool that can assess the symptoms of long COVID has been developed at the University of Birmingham. Currently, more than 200 symptoms are associated with long COVID. These can affect many organs in the body and include breathlessness, fatigue, or brain fog and are estimated to affect around 1.3 million people in the UK. Patients can use the Symptom Burden Questionnaire to report symptoms and the data can be used to help identify treatments, and test whether these are safe and effective.

bit.ly/3scEH2e

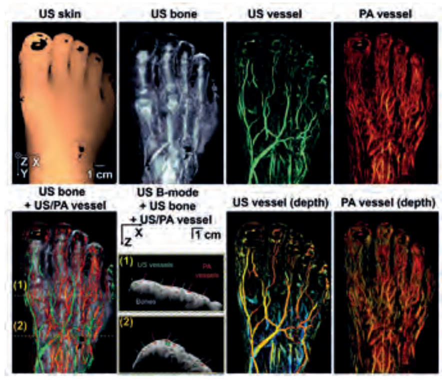
Antibody measurement technology

A cross-disciplinary team coordinated by scientists at Mason's Centre for Infectious Disease Research has developed the hybrid alphavirus-SARS-CoV-2 pseudovirus system, which can robustly express reporter genes in cells within hours to rapidly measure neutralising antibodies. Ha-CoV-2 pseudovirus was utilised against the COVID-19 virus and its variants including Alpha, Delta, and Omicron, as well as the currently emerging omicron BA.2 variant.

bit.ly/3vWL6iU

RESEARCH AND DEVELOPMENT

3D BIMODAL PHOTOACOUSTIC ULTRASOUND IMAGING



A Korean research team has developed a 3D foot imaging technique that vividly captures peripheral blood vessels – even thinner than 1 mm.

The researchers developed an imaging technique that combines the photoacoustic and ultrasound images. Conventionally, the ankle-brachial index test was used to measure the blood pressure of the wrist, ankle, or toe to calculate the ratio to diagnose peripheral vascular diseases.

As for imaging modalities, the Doppler ultrasonography, which measures the blood flow, angiography using computed tomography (CT), or magnetic resonance imaging (MRI) were widely used.

Although these methods can detect abnormalities in major arteries, they have limitations in clearly capturing the thin and numerous peripheral blood vessels. They can also cause pain or side effects because a contrast agent must be injected into the patient.

To overcome these issues, the researchers combined photoacoustic and ultrasound images to and visualise 3D images of blood vessels thinner than 1 mm without a contrast agent by. Using the photoacoustic effect – in which sound waves are formed following light absorption in a material – blood vessels in the body can be imaged using the light absorption of the blood without a contrast agent.

bit.ly/3Fe3Vm5

UP CLOSE

PFAS

WHAT ARE PFAS?

The acronym stands for perfluoroalkyl and polyfluoroalkyl substances, which are a large, complex, and ever-expanding group of manufactured chemicals that are widely used to make various types of everyday products.

WHAT ARE SOME OF THEIR USES?

They keep food from sticking to cookware, make clothes and carpets resistant to stains, and create firefighting foam that is more effective. PFAS are used in an array of industries, such as aerospace, automotive, construction and also electronics.

WHAT IS THE LATEST NEWS?

Exposure to PFAS is connected to liver damage, according to a new study conducted by researchers from the Keck School of Medicine of the University of Southern California.

TELL ME MORE.

This is the first study to systematically review the data on PFAS exposure and damage to the liver, synthesising the results of 111 peer-reviewed studies involving both humans and rodents.

WHAT DID THEY FIND?

They concluded that three of the most commonly detected PFAS in humans are all connected with elevated levels of alanine aminotransferase (which is a biomarker for liver damage when elevated) in the blood of both humans and rodents.

WHERE CAN I READ ABOUT THE STUDY?

Type **bit.ly/3yut8Yj** into your browser.

OBSERVATIONAL STUDY

SYMPTOM DATA TO HELP PREDICT COVID-19 ADMISSIONS

Swedish researchers are conducting one of the largest citizen science projects in Sweden to date.

Since the start of the pandemic, study participants have used an app to report how they feel daily even if they are well.

This symptom data could be used to estimate COVID-19 infection trends across Sweden and predict hospital admissions due to COVID-19 a week in advance. The results have now been published in *Nature Communications*.

The analyses included more than 10 million daily reports from participants in the COVID Symptom Study Sweden from April 2020 to February 2021.

The app used for data collection was originally developed by ZOE, a health science company, with support from physicians and researchers at King's College London and Guy's and St Thomas' Hospitals.

go.nature.com/3ydnB89

MAGNETIC RESONANCE IMAGING

"PORTABLE MRI ALMOST AS EFFECTIVE AS STANDARD MRI"

Portable MRI machines detected ischemic strokes, or strokes caused by clotting, in 90% of patients scanned, according to a study led by Yale and Harvard researchers.

Previous studies have shown that portable MRI devices can also detect strokes caused by bleeding in the brain, which are distinct from strokes caused by brain clots.

The ability of portable MRI machines to differentiate the two types of stroke will help clinicians

make life-saving treatment decisions quickly for patients who lack ready access to major hospitals.

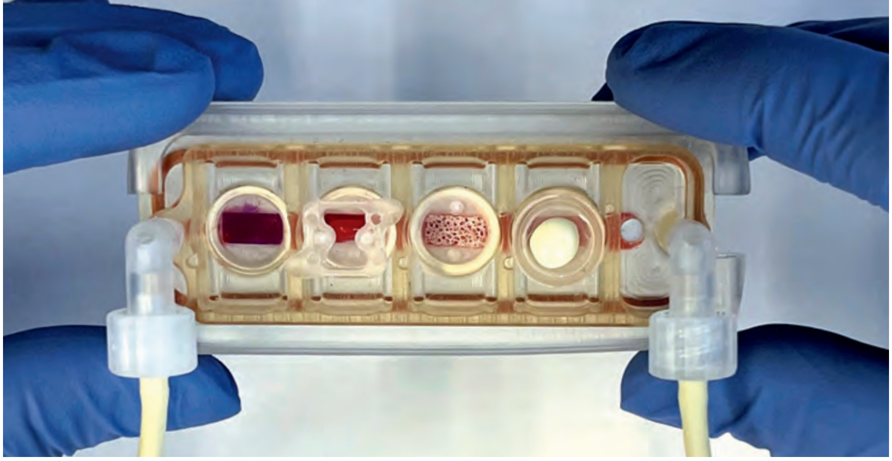
Kevin Sheth, study co-author, said: "This is the first systematic evidence you can detect ischemic strokes using portable, bedside devices."

In an analysis of portable MRI scans from 50 patients researchers found that the results largely confirmed ischemic stroke diagnoses made by stationary MRIs.

For 45 of those patients, the portable MRI detected blood clots as small as 4 millimetres in size.

Portable scans can be employed at a patient's bedside, in ambulances, or at clinics in remote areas, Sheth said.

bit.ly/39Diu71



Multi-organ chip with vascular flow

A model of human physiology has been developed in the form of a multi-organ chip consisting of engineered human heart, bone, liver, and skin that are linked by vascular flow with circulating immune cells, to allow recapitulation of interdependent organ functions.

The researchers from Columbia Engineering and Columbia University Irving Medical Centre have essentially created a plug-and-play multi-organ chip, which is the size of a microscope slide, that can be customised to the patient.

Because disease progression and responses to treatment vary greatly from one person to another, such a chip is hoped to eventually enable personalised optimisation of therapy for each patient.

Project lead Gordana Vunjak-Novakovic said: "This is a huge achievement for us – we've spent 10 years running hundreds of experiments, exploring innumerable great ideas, and building many prototypes, and now at last we've developed this platform that successfully captures the biology of organ interactions in the body."

The group created tissue modules, each within its optimised environment and separated them from the common vascular flow by a selectively permeable endothelial barrier.

The individual tissue environments were able to communicate across the endothelial barriers and via vascular circulation.

The researchers also introduced into the vascular circulation the monocytes giving rise to macrophages, because of their important roles in directing tissue responses to injury, disease, and therapeutic outcomes.

bit.ly/3Gp72Xn

IMAGES: TEXAS A&M ENGINEERING / ISTOCK

MEDICAL IMAGING

VIDEO RADIOLOGY REPORTS FOR PATIENT-CENTRED CARE

Video radiology reports have the potential to improve communication with patients, it is claimed.

Scientists at New York University's Grossman School of Medicine collaborated with Visage Imaging GmbH to build an integrated video-reporting tool inside the diagnostic viewer, allowing for both image and voice capture.

To aid patient understanding of cross-sectional images, cinematic rendered images were automatically created.

For their incorporation into video reporting, these images were immediately available at the workstation.

Video radiology reports were then uploaded to the institutional health portal, alongside clinical notes and examination images.

Finally, a 10-question survey was administered to patients, assessing their perception of the video reports.

Lead researcher Michael P. Recht said: "The mechanism of creating the video reports and delivering them to patients

ONCOLOGY

Wireless device for colorectal cancer treatment

A US team is working to develop a low-cost, minimally invasive wireless device to eliminate leftover cancer cells during surgery, reducing the need for additional treatments, such as chemotherapy

The researchers will utilise photodynamic therapy (PDT) during surgery by using a photosensitiser – a drug activated by light – to kill the cancer cells. During this process, surgeons will be able to remove the bulk of the tumour, then fully irradiate the tumour bed when the photosensitiser is activated by the light. This combination should result in a complete treatment in a safe and effective way with no toxic side effects, they claim.

Sung Il Park, Assistant Professor in Electrical and Computer Engineering, said: “The biocompatible, miniaturised implantable LED device will enable light dosing and PDT that is tailored to the individual tumour response.”

In the long term, the work will result in a platform that has the potential to provide clinical-quality health monitoring capabilities for continuous use beyond the confines of traditional hospital or laboratory facilities.

It will also allow for treatment options to prevent the development of additional malignancy and therefore significantly improve the quality of life for people with cancer.

go.nature.com/3MKbMKw

can be integrated into existing informatics infrastructure.”

Faculty radiologists created a total of 3763 video radiology reports, with patients viewing 864 unique videos.

Based on 101 survey respondents, patients rated their overall experience with video radiology reporting a 4.7 out of 5.

Specifically, Recht and colleagues state that video radiology reports using lay language and annotated images helped improve patients’ understanding of their results.

bit.ly/3w3bO9V

CLINICAL RESEARCH

Automated nutrition app can help people follow healthier diet

People could benefit from fully automated personal nutritional advice, as a new research paper shows that an app improved healthy diet in clinical trials.

Participants who were given automated personalised nutrition advice from the eNutri app improved their healthy diet score by 6% compared to a control group who were given general healthy eating guidance.

Dr Rodrigo Zenun Franco, lead author of the paper, said: “The eNutri app prioritises healthy eating based on evidence and uniquely uses a diet scoring system to provide food-based advice that is tailored to the individual user.”

People were either assigned to receive personalised nutrition advice or given general healthy eating advice. Those in the personalised group then had their diets scored according to 11 criteria based on UK dietary guidance. The eNutri app gave an automated assessment of diet quality giving the user a “healthy diet score”.

The healthy diet score includes assessments of intake of fruit, vegetables, wholegrains, red and processed meat, with higher points awarded when users have the recommended intake of these.

The personalised advice is then targeted to areas of their diet that would benefit most from changing.

bit.ly/3saKZQ2

EXTERNAL RELATIONS MANAGER

Cancer services under scrutiny

Sean Edmunds, the Institute's External Relations Manager, outlines the latest policy news and Institute updates.

Cancer services and the Government's commitment to improve them came under scrutiny earlier this year.

Two reports from the House of Commons Health and Social Care Committee were released, which said the Government was making "inadequate" progress in this area - and IPEM commented on both of them.

An evaluation by the Committee's Expert Panel on Cancer Services rated Government progress as "inadequate", and a second report published days later found the NHS in England is struggling to make progress on diagnosing three-quarters of cancer cases at an early stage due to staffing shortages and on-going disruption from the pandemic.

IPEM provided input to both the Expert Panel and the cancer services consultation by the Committee, which looked at why cancer outcomes in England continue to lag behind comparable countries.

The Expert Panel focused on progress made on five policy area commitments. Those relevant to IPEM were:

- Workforce – progress was shown overall as "inadequate"
- Diagnostics – "requires improvement"
- Innovation and technology – "requires improvement".

Nicky Whilde, Chair of IPEM's Radiotherapy Professional Standards Panel, said: "It comes as no surprise to those professions in IPEM working in radiotherapy that the conclusion drawn by the Expert Panel regarding progress against Government cancer commitments is that it 'requires improvement'."

Andrew Shah, IPEM's representative on the National Imaging Workforce Group, added: "The growth in workforce is needed to improve referral to diagnosis and referral to treatment targets and to implement new technologies, which all combined will improve patient outcomes."

The findings echo IPEM's submission to the consultation last year, namely a need for capital investment in ageing linear accelerators, workforce shortages in key areas and the need to fund more training places in specialist roles.

IPEM made similar arguments in a submission to a recent Department of Health and Social Care 10-Year Cancer Plan consultation.

Several IPEM Special Interest Groups and the Radiotherapy Professional Standards Panel provided input to that consultation, and there were three areas which were commented on:

- How to get more people diagnosed quicker included suggestions around the Community Diagnostic Hubs to start rapid MRI screening, better support for patients with implants who need MRI scans, and the funding of accelerated MRI techniques.
- How to improve access to experiences of cancer treatment included suggestions about ensuring there is an adequate supply of medical radionuclides for both diagnostic and therapeutic purposes, supporting centralised funding for a country-wide replacement programme for radiotherapy equipment, and an initiative to increase access to new Artificial Intelligence technologies for radiotherapy.
- How to maximise the impact of research and data regarding cancer services focused on IPEM's concerns around workforce shortages, especially in radiotherapy and the diagnostic radiology and radiation protection areas.

Professor Andrew Reilly, Director of IPEM's Science, Technology and Engineering Research and Innovation Council, said: "The response once again highlights the workforce shortages faced by the medical physics and clinical engineering community.

"We all know there are staff shortages right across the NHS but we really do need to see those in MPCE addressed because of the potential impact on patients."

Further commentary on the consultations are on the IPEM website: **ipem.ac.uk/news** and you can read the consultation responses in full at **ipem.ac.uk/about/public-engagement/consultations**

IMAGE: GETTY IMAGES

OTHER IPEM ACTIVITIES AND WORK

Last year IPEM brought together a group of like-minded organisations to explore how clinical technologists might become statutory registered professionals to help deliver better patient outcomes.

A number of meetings were held with a wide range of bodies and individuals to ascertain their views on the current situation and the likelihood of achieving statutory registration.

At the time of writing, the coalition of organisations was looking at the outcomes of those meetings to agree on a way forward.

It was agreed that IPEM would submit a joint response on behalf of the coalition to the Department of Health and Social Care consultation "Healthcare regulation: deciding when statutory registration is appropriate". IPEM, along with the coalition members, also submitted an individual response to this.

IPEM also collaborated with the Royal College of Radiologists and the Society of Radiographers to produce updated guidance for NHS providers of diagnostic imaging services.

The "Diagnostic imaging network workforce guidance" was supported by the three organisations, which seeks to maximise the utilisation of the current workforce within imaging departments through networks by improving working environments and sharing good practice, as well as guide planning for the future growth of the workforce.

Finally, in the spring IPEM began the process of seeking "Investing in Volunteers" accreditation. This is a quality standard that aims to improve the quality of the volunteering experience.

Volunteers will be fully involved in the process and more information will be made available about this later in the year.

> **IN THE SPRING IPEM BEGAN THE PROCESS OF SEEKING "INVESTING IN VOLUNTEERS" ACCREDITATION**

ENVIRONMENTAL SUSTAINABILITY

Laura Perry reflects on progress and learning points from the last 12 months for the Imaging-Environmental Sustainability Group at Imperial College Healthcare NHS Trust.

The World Health Organisation has stated that climate change is the single biggest threat to human health. This is based on the impact of rising seas and flooding on drinking water and waste treatment increasing risks of waterborne diseases, the impact of fires on air quality leading to rising cases of asthma, acute bronchitis and pneumonia and higher temperatures leading to heat exhaustion, heatstroke, hyperthermia and dehydration. Paradoxically healthcare itself makes a huge contribution to climate change with the NHS generating 4% of the UK's carbon footprint.

Individuals and companies are increasingly aware of the issues and are taking steps to reduce their impact on climate change. In 2020 the NHS became the first healthcare system in the world

IMAGES: GETTY

to set a target to reach net zero. The target date to reach net zero is 2045. In England, this will be achieved through "green plans" developed by each NHS organisation to record and outline their carbon reduction initiatives to achieve the required reduction in emissions. Input and participation from individual staff members will be key to achieving the targets.

98%
Reduced use of burns bins

CO_2

20,513kg
Reduction of carbon dioxide equivalent emissions

800%
Increase in recycling bin provision

Reflecting on progress

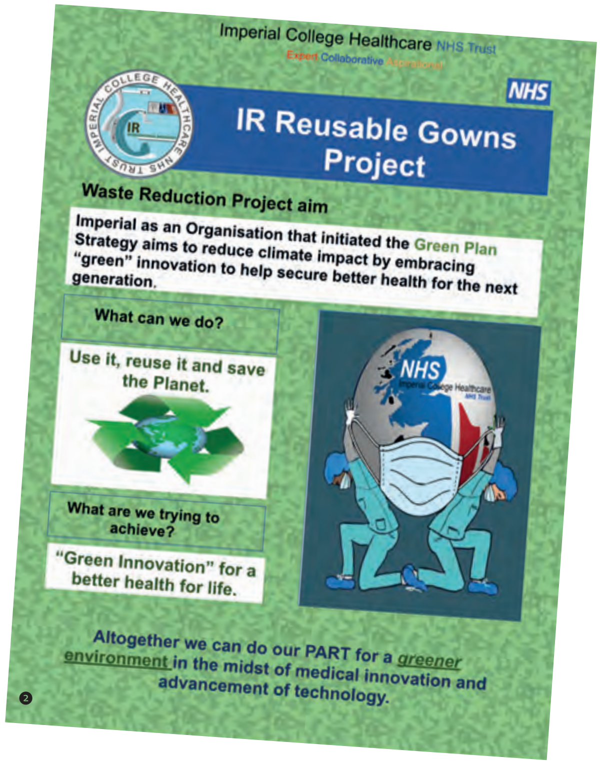
During a fortnightly all-staff briefing from the Chief Executive of Imperial College Healthcare NHS Trust, a nurse working in the same imaging department as myself asked a question about reusable personal protection equipment (PPE) and environmental sustainability. After contacting the nurse to share my interest in climate change and environmental sustainability, we decided to establish the Imaging department Environmental Sustainability Group (I-ESG) to improve the sustainability of the department. After a year as a member and a co-chair of I-ESG, I am reflecting on the group's progress in this article and sharing learning points that may aid similar initiatives in other departments and healthcare organisations.

Our environmental sustainability group includes 26 active, self-nominated members across all department staff groups including clinical scientists, managers, radiologists, radiographers, nurses, healthcare assistants, administration and clerical staff. There are two co-chairs elected by the members. The group aims to promote environmental sustainability to and within the department, support and undertake projects to improve the environmental sustainability of the department and engage with others, including manufacturers and other trust departments on environmental sustainability. The group holds monthly virtual meetings with each member encouraged to contribute ideas and comments respectfully as we discuss, support, and mentor ongoing projects and new ideas and share opportunities for group members to get involved in sustainability work. We utilise the Trust Quality Improvement Framework to guide our projects and the group work is reported upwardly through established management structures. The group is recognised as helping to develop and demonstrate staff engagement, which fits within the CQC inspection framework for the "well-led" standard.

In the year since the I-ESG was established the group has initiated work reducing carbon equivalent emissions in the imaging department. One of our first projects, run by our radiographers, was to review waste pathways as correct segregation can reduce the environmental impact of the disposal route involved. After auditing waste pathways in CT, changes were made which reduced the use of burns bins by 98%. Based on data provided by our waste management service, this reduced carbon dioxide equivalent emissions by an estimated 16% (20,513kg per year). There was also an 85% reduction in the cost of processing this waste (just under £10,000 per year). We have also re-established the collection and recycling of unused, residual CT contrast and started recycling the rinsed and de-labelled bottles. Communication and discussion with all relevant staff to share the reasons and results of these projects has been essential to achieving high levels of compliance. Imperial College Healthcare Trust operates across multiple sites and by sharing practice and rolling out successful waste initiatives trialled at one site to all the others, we have been able to multiply the impact of our work quickly. Visible projects completed in this

"

COMMUNICATION TO SHARE THE RESULTS OF THESE PROJECTS HAS BEEN ESSENTIAL



❶ Measuring the mass of ultrasound gel bottles to help calculate environmental impact of their disposal

❷ Locally produced poster to raise awareness of re-usable PPET project

area have also fostered support for further initiatives with recent management support for a massive 800% increase in recycling bin provision and a new project implementing the recycling of ultrasound gel bottles.

Another project, coordinated by nurses working in our interventional-radiology (IR) suites, focused on re-usable sterile gowns. The Trust Green Plan team facilitated collaboration with theatres staff who were also interested in exploring re-usable PPE. By working collaboratively initial ideas were quickly developed and an eight-week trial was planned and completed. During the trial, gowns were collected after use, washed and re-sterilised and returned to us for re-use by the company that manages scrubs across the trust. After 70 uses the gowns are retired from use and recycled or reused in other settings. Feedback from our IR teams was requested before, during and after the trial with over 91% of staff happy with the new gowns. Early analysis from the trial indicates 6,500Kg CO2 emissions and £10,000 saving per year for the department. This data has been used to support a trust business plan to move to re-usable sterile gowns saving an estimated 234,660 Kg CO2 and £27,131 per year.

There are other projects big and small that the group has completed which may be of interest to readers who would like to complete an improvement project in their own healthcare organisation (see box, right).

OTHER PROJECTS

- Switching the disposable cups provided by water points from un-recyclable polystyrene to recyclable plastic. This was facilitated by changing the default item order code through collaboration with colleagues in purchasing. By coupling this change with the improved position of recycling bins we aim to increase the proportion of waste recycled.
- We ran an X-ray film amnesty collecting obsolete films for recycling and resource recovery. A total of 6.5 tonnes of X-ray films were collected and recycled with the funds from recovered materials more than covering the cost of the project.
- Supporting projects to reduce resources used in clinical studies. A Clinical Scientist in the group contributed to local work implementing single scan SeHCAT studies based on published work. Such projects reduce the carbon footprint of a particular study by reducing the energy used for image acquisition and the share of the embodied emissions of the imaging equipment.
- Promoting continued video consultation for patients where equivalent, practical and safe. Early in the COVID-19 pandemic this practice was established during patient work-up for I-131 therapy for hyperthyroidism. This practice continues to date with 96% of these consultations run by our nuclear medicine team now performed using video or telephone conferencing. The reduced patient travel associated with virtual consultation has been shown to produce carbon footprint savings.

Success of initiatives

While individual I-ESG members working alone or in small groups have undertaken most of the quality improvement projects to date, their impact is magnified through the formal backing of the group and the connections and contacts that it facilitates. As a group we have been able to contribute to wider Trust Green Plan working groups, reviewing staff training in environmental sustainability, waste management, models of care and sustainable redevelopment of the trust estate. Two-way feedback on the Trust Green Plan work in progress is shared and collated in I-ESG meetings, enabling participation on a scale greater than any of us could achieve on our own. Sharing successful trials of initiatives run in a single small area, with the whole I-ESG has also led to quick adoption across Trust sites and imaging modalities which have historically been less integrated. We have also been able to quickly volunteer and participate in trials of new initiatives as I-ESG enables staff across the department to mobilise quickly. An example of this was a trial of IT software to automatically turn off unused computers at night which we hosted within our department. The data from this trial have been included in the recently approved, trust-wide business case for further roll-out of this project.

FURTHER ACTIONS

- **Read** - *How Bad are Bananas? The Carbon Footprint of Everything* by Mike Berners-Lee to learn more about important contributions to carbon footprints.
- **Listen** – "Reasons to be Pirate" episode (27/04/2018) from *Reasons to be Cheerful* with Ed Miliband and Geoff Lloyd" podcast to get inspired to take action.
- **Join** – The IPEM Environmental Sustainability Group to connect with your peers undertaking work in this area.

The success of all the initiatives coordinated by I-ESG has relied on department staff engagement. As part of our aim to engage with directorate staff we completed a survey of the department in July 2021 to establish baseline awareness and enthusiasm regarding environmental sustainability. The results were presented in a department meeting together with our initial planned initiatives. In total, 75% of responders were very or extremely interested in environmental sustainability and were active in reducing their carbon footprint at home and engaged in ideas to improve sustainability at work. Maintaining and building on wider department staff engagement with I-ESG work has been key to achieving compliance with initiatives with the associated, impressive results.

Members of I-ESG have also engaged with our peers outside our own trust through a range of activities. We have contributed content and articles to journals to share our work and best practice. Group members have engaged and presented work to the Royal College of Radiologists and at the AxREM Environmental Sustainability Roundtable in December 2021. I also participate in the IPEM Environmental Sustainability Group and have found sharing ideas between different

3

"THE GROUP HOLDS MONTHLY VIRTUAL MEETINGS WITH EACH MEMBER ENCOURAGED TO CONTRIBUTE IDEAS

groups a great way to develop new ideas and refresh stagnated projects through the dissemination of ideas, results and achievements across healthcare organisations.

In reviewing the position of I-ESG on its first birthday, I see a healthy group with growing membership and interest from the wider department. I am incredibly proud of the improvements and achievements to date and feel the confidence of the group is growing as changes are implemented with positive results. Participation in the group provides support and mentorship to ease project roadblocks and facilitate vital connections with key players in other external departments. Engagement with the wider Trust Green Plan and external bodies has seen the I-ESG acting as early adopters or a trial department for new initiatives. I am excited to see what the next year will bring!

❸ A monthly meeting of the I-ESG

❹ A re-usable sterile gown modelled by the IR team

The takeaways

The main learning points of our group have been:

- Collaboration is key. Individual staff members are already incredibly busy with clinical work. Connecting people with the right mix of enthusiasm, knowledge and skills will lead to successful improvement projects even in the most challenging situations.
- There are benefits to working in groups of all sizes and flexibility is useful. Small, agile groups can drive change they are passionate about. Support and backing from a wider group is helpful when issues arise and to amplify and promote the resultant work.
- Sharing practice between modalities, specialisms, sites and healthcare organisations can help drive and multiply change. Being able to cite an example of change implemented elsewhere has been great motivation and evidence to drive change locally.

As a medical physicist, I have been able to utilise the skills and experience that I have gained working as a Clinical Scientist to support the I-ESG. I have been able to support colleagues in quantitative analysis of environmental sustainability projects through my experience manipulating spreadsheets and working with statistics. Experience of audit from optimisation and legislative compliance work has been helpful, especially when combined with an analytical approach to problems, boosted by years of practical problem solving in clinical work I have found applying these transferable skills to environmental sustainability has been rewarding and enjoyable. Finally, for those who are interested, see the "Further Actions" box on the previous page for some suggested actions.

***Laura Perry** is the Principal Nuclear Medicine Physicist and co-chair of the Imaging Environmental Sustainability Group at Imperial College Healthcare NHS Trust.* *She would like to thank her fellow co-chair, Dr Sarah Sheard, Consultant Cardiothoracic Radiologist, and all members of I-ESG who have led and contributed to the work discussed above.*

1

❶ Maria Goeppert Mayer.

❷ Joseph Mayer and Maria Goeppert Mayer, 1930.

Another Nobel Physics prize

A DIFFERENT MARIA

David Thwaites considers Maria Goeppert Mayer, the second woman to win a Nobel Prize in Physics, and the context of her work.

In the first of an occasional series of "historical fragments" of interest to medical physics published in the spring issue of *Scope*, I discussed some aspects of names and naming relevant to Maria/Marie Sklodowska-Curie's life and work, from her Polish roots to her family's Nobel prizes.

As an aside, she gained many other awards and can be seen AND heard in a digitally restored Pathé news clip from 1931, receiving the American College of Radiology Gold Medal. This was three years before her 1934 death at 66 years old. Visit **bit.ly/3vBLwv5** to see the clip.

Her part of the 1903 physics Nobel prize was joint with her partner Pierre (for their "joint researches on the radiation phenomena discovered by Professor Henri Becquerel"). They shared the prize with Becquerel for his "discovery of spontaneous radioactivity".

The 1903 prize was the third, the first having gone to Röntgen in 1901. Marie Curie is famously the first woman to be awarded the prize. Until 2018 there had only been one other woman Nobel laureate in Physics – Maria Goeppert Mayer ❶ in 1963. This partly reflected the fact there were fewer women physics researchers, particularly in senior research roles, but also continuing discrimination, as indicated by well-discussed cases of women researchers not being recognised, such as Lise Meitner, Rosalind Franklin and Jocelyn Bell.

This second woman to be awarded a physics Nobel prize had some interesting parallels with Maria Sklodowska-Curie. She was also named Maria, also came from what is now Poland, was also enthused into science by her father, also emigrated and conducted her scientific career abroad and also had to deal

IMAGES: ALAMY

with academic discrimination against women. Furthermore, her Nobel prize work on nuclear structure has a direct lineage to the Curies' work.

Development of nuclear physics

Nuclear physics began, as distinct from atomic physics, from Becquerel's discovery of what the Curies named radioactivity and from their extensive investigations of radioactive materials and applications. This work was initiated by Marie and continued and expanded by her after Pierre's untimely death and taken up by many others, including Rutherford. The Curies' discovery of radioactive elements provided tools for the exploration of the structure of the atom, notably the Geiger-Marsden experiment under Rutherford's supervision, using alpha particles from radon that were observed to scatter off thin metal foils, as well as travel through. This was totally unexpected in the then popular "plum-pudding" model of the atom proposed by JJ Thomson (to align his work on the electron with the fact that atoms are electrically neutral). It led to Rutherford's 1911-13 nuclear atom model and thence to the whole field of nuclear physics and particle physics. After Chadwick identified neutrons in 1932, the theory of the nucleus containing protons and neutrons developed rapidly. This explained nuclear spins and accounted for beta-decay (Fermi in 1934). Also in 1934, Irène and Frédéric Joliot-Curie used alpha particle bombardment to produce new artificial radioactive elements, jointly gaining the 1935 Chemistry prize for this work. From 1934, Fermi and others chose to use neutron bombardment of various elements, including uranium, showing the production of new radioactive isotopes, assumed to be transuranic. Fermi received the 1938 Nobel Physics Prize for this work and for his discovery of nuclear reactions using slow neutrons. Hahn, Meitner and Strassmann repeated and extended Fermi's work, also from 1934, leading to the almost reluctant realisation in 1938 that neutron bombardment of uranium produced nuclear fission. Meitner and O.R. Frisch explained this with the liquid drop model. The scene was set for the development of nuclear reactors and nuclear bombs in the 1940s and for nuclear medicine and therapy based on artificially produced isotopes. Hahn alone received the 1944 Chemistry prize for the discovery of fission (announced by the Nobel committee in 1945 after the end of WWII in Europe, but before the dropping of atomic bombs on Japan. At the time, he was being held in Farm Hall, near Cambridge, with nine other scientists involved in Germany's nuclear programme, while the Allies pieced together how near to creating an atomic bomb they had got).

" THE SCENE WAS SET FOR THE DEVELOPMENT OF NUCLEAR BOMBS

3 Maria Goeppert Mayer walking in to the Nobel ceremony with King Gustaf Adolf.

4 (Left to right) Joseph Mayer, Maria Goeppert Mayer, and Karl Herzfeld in Washington, DC for an American Physical Society meeting, taken outside the National Academy of Sciences.

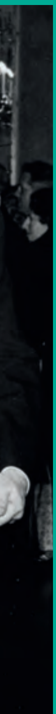
5 Maria Goeppert Mayer around the time of the Nobel prize announcement.

6 Hans Jensen.

Maria Goeppert Mayer

So, where does Maria Goeppert Mayer fit in? Maria Göppert (later anglicised/phoneticised to Goeppert) was born in 1906 in then Kattowitz in the German Empire in the Silesian province of Prussia (later Katowice, Poland). Her father became Professor of Paediatrics in Göttingen University when she was four and she entered that university in 1924 to study maths, but soon became more attracted to physics. Her 1930 PhD thesis developed the theory of two-photon absorption (TPA) by atoms, a third-order process where both photons are absorbed simultaneously. TPA now has applications in, among other things, optical imaging, photodynamic therapy and optical data storage, but her prediction of it could only be successfully verified more than three decades later with the availability of lasers. The unit of TPA absorption cross-section is named after her, the GM, 10^{-50} cm^{4} s photon^{-1}.

In 1930, she married the US scientist, Joseph (Joe) Mayer 4, a physical chemist who had been working with James Franck for a year and boarding with the Göppert family. Maria emigrated to the US the same year, when Joseph took up a post in Johns Hopkins University (JHU), Baltimore. Here she met academic and scientific discrimination against women. JHU, along with many US universities, had anti-nepotism rules to prevent patronage in awarding jobs. Whilst originally created for positive reasons, they were often used to prevent academics' wives taking faculty posts. Maria was offered a low-paid assistant's job, but achieved significant work, including proposing double



beta decay, which took until 1987 to be experimentally observed from ^{82}Se.

Joseph moved to Columbia University, New York, in 1937, where Maria obtained an office in the physics department, but no salary. She worked "for the fun of doing physics". This also positioned her to work with Fermi who arrived there in 1939 and Harold Urey (1934 Physics prize for discovering deuterium). In late 1941, she began a part-time paid job at the Sarah Lawrence College, New York, but not long afterwards was requested to join the Manhattan project in Urey's group back at Columbia, as a part-time researcher investigating ways to separate fissile U-235 from natural uranium. This led to a post with Teller's Columbia group and then in the Los Alamos lab, investigating characteristics of matter and radiation at very high temperatures, in support of bomb-related projects.

IMAGES: ALAMY, AIP

Nuclear shell structure and the Nobel prize ❸

In 1946, Joseph moved to the chemistry and nuclear studies departments in the University of Chicago, where Maria became a voluntary (i.e. still no salary) assistant physics professor ❹. The Argonne National Lab opened near Chicago soon afterwards and she was offered a part-time senior physicist post in the theoretical physics division, to which her initial response was: "I don't know anything about nuclear physics." Here, she developed her ideas, and a mathematical model, of nuclear shell structure, published in 1949. This explained why the so-called "magic numbers" of nucleons produced particularly stable nuclei, with tighter binding than the next higher number ❺. Her insight was that the nucleons are in closed shells and that pairs of protons and neutrons tend to couple, which was partly prompted by a throwaway question from Fermi about spin-orbit coupling. Her analogy was of a room full of waltzing couples in concentric circles, some circling clockwise and some counter-clockwise and some of each group also twirling (spinning) clockwise and some counter-clockwise. Maria proposed a theory of fission based on her nuclear shell model, which better explains the nuclear fission process and products than the liquid drop model, which predicts fission products of the same size. At the same time, three German researchers independently proposed similar shell models. Maria collaborated with them, producing a book on nuclear shell structure with J. Hans D. Jensen ❻. Maria and Jensen shared half the 1963 Physics prize for their work on nuclear shell structure. The other half went to Eugene Wigner, the Hungarian-American physicist, for contributions to the theory of the atomic nucleus and elementary particles, particularly through the discovery and application of fundamental symmetry principles.

From 1960, Maria was a full professor of physics at the University of California, San Diego, with a San Diego newspaper hailing her award with the headline "S.D. mother wins Nobel Prize". It had been 60 years since Maria Sklodowska-Curie's award and would be another 55 years before the next woman Physics laureate, the Canadian Donna Strickland in 2018, for work in laser physics.

Maria Goeppert Mayer died in 1972 and, as well as our understanding of nuclear structure and processes, her legacy includes a number of named awards in the US created to support and encourage women scientists.

David Thwaites *is Professor of Medical Physics at the University of Sydney, Australia, an honorary Professor of Oncology Physics at the University of Leeds and a Fellow of IPEM.*

Inclusivity in medical physics

FEAR LESS, UNDERSTAND MORE

Healthcare Scientist **Erin Donovan** explores the issues around equality, diversity and inclusion and looks at the positive actions that we can all take.

IMAGE: GETTY

I chose a career in healthcare science because, along with having an interest in physics, I wanted to work in a field where I could make a tangible difference, and I feel that the majority of IPEM's membership will share this sentiment. As part of this, we regularly ask ourselves how we can make improvements to our services, and the answers usually revolve around equipment, staffing levels or additional training. These are all valuable avenues to explore, but we often overlook the power of promoting equality, diversity and inclusion (EDI) within our organisations.

Equality, diversity and inclusion

EDI is a term you may have only come across when completing your mandatory training module, and then haven't thought about since. So what do we actually mean when we talk about EDI? Equality is the state of being equal, especially in status, rights, or opportunities, and this is protected in the UK by the Equality Act (2010). Diversity empowers people by respecting and appreciating what makes them different, and this extends beyond simple tolerance to ensure we understand and value other people's differences. Inclusion is achieved by implementing practices in which groups and individuals with different backgrounds are accepted, welcomed and equally treated. Inclusive cultures make people feel respected and valued for who they are.

The Equality Act (2010) prohibits all employers, service providers and providers

IMAGE: GETTY

of education from discriminating against, harassing or victimising people with protected characteristics, which includes but is not limited to: age, sex, race, religion or belief, disability, sexual orientation, and gender reassignment. Many large organisations will have dedicated EDI teams to ensure that all policies and procedures are designed to meet the requirements of the Equality Act, and to protect staff and service users from unlawful discrimination. However, EDI is the responsibility of everyone and we can all make changes in our workplaces.

Demographics

The legal aspect aside, it's important to understand why EDI matters. This can be done by looking into the demographics of IPEM and the UK as a whole. IPEM's last EDI survey was conducted in 2017, but, unfortunately, the 20% response rate means that it cannot be used to draw reliable conclusions about the diversity of the membership. IPEM does record sex as part of the membership data, and the current split is 40% female and 60% male. The Office for National Statistics released population data for England and Wales in 2019, and this can be used to estimate how many people have a protected characteristic:

- **Ethnicity** – 15.19% are non-white i.e. (Asian or Asian British; Black, African, Caribbean or Black British; Mixed or multiple ethnic groups; other ethnic group)
- **Religion** – 61.57% are religious; 10.55% are non-Christian (Buddhist, Hindu, Jewish, Muslim, Other, Sikh)
- **Sexual orientation** – 1.4 million people (16+) identified as LGB (equates to 2.7% of UK population)
- **Disability** – 23% identify as having a disability matching the Equality Act definition.

From this data, it's fairly clear that you will routinely encounter people with at least one protected characteristic at work, either as colleagues or service users, and it's important that you know how to respect and include people's differences.

The rest of this article will give additional background information about sex and gender, and provide practical examples of how to be more inclusive. I would like to take this opportunity to note that I will be focussing primarily on LGBT+ inclusion, as this is my lived experience as a person who is non-binary and queer, but the general principles can be applied to any situation.

Sex and gender

The terms "sex" and "gender" are often used interchangeably, but they are two distinct concepts. Sex refers to the physical differences between people, and a person will typically have their sex assigned at birth based on physiological characteristics, including their genitalia and chromosome composition. Gender is often expressed in terms of masculinity and femininity, is largely culturally determined and is assumed from the sex assigned at birth. When someone's gender matches the sex that they were assigned at birth, they can be referred to as cisgender. However, gender does not always align with the sex assigned, and someone's gender identity may be male, female or something else.

In the instances where someone's gender doesn't match their sex assigned at birth, they can be referred to as transgender (or trans for short). This is an umbrella term that covers trans men (someone assigned female at birth but who lives as a man), trans women (someone assigned male at birth but who lives as a woman) and non-binary people (people whose gender identity doesn't sit comfortably within the binary of male or female).

Sex is slightly more nuanced than people being simply male or female, as some people have differences in sex development, which can also be referred to as being "intersex". This is a term used to describe a person who may have the biological attributes of both sexes or whose biological attributes do not fit with societal assumptions about what constitutes male or female.

When talking about people who do not fit into the conventional expression of sex or gender, it's important to use the most respectful terms possible that are still fully inclusive, e.g. "Transgender, non-binary and intersex" covers every possible identity with regards to sex and gender outside of our usual experiences. Although terms such as "gender variant" or "gender incongruent" are clinically recognised, they can have negative connotations for people as they are diagnoses rather than a description of a person's identity.

Inclusivity in practice

When thinking about how to make overarching improvements to services it can feel daunting, but if we instead think of the smaller, positive actions required to achieve this outcome, we are more likely to succeed in enacting meaningful change.

One of the key barriers to improving inclusivity is our implicit (or unconscious) bias. This is developed from stereotypes and assumptions that we make about certain groups of people. There are several types of assumptions, but the most relevant one in this instance is called a "paradigmatic assumption", which is used to structure the world into fundamental categories. It's important to listen to your internal dialogue and note any existing biases so that you can then work on challenging them.

We automatically categorise people by sex into being either male or female, which we've already established does not include people with differences in sex development. The societal default with respect to gender is to assume that people are cisgender, and fall within the binary of male or female, which is not true in the case of transgender and non-binary people. When considering sexual orientation, the default assumption is that people are heterosexual or straight, but this is not true for approximately 2.7% of the UK population.

When talking to someone about their relationship status, instead of asking "do you have a husband/wife/boyfriend/girlfriend?", it's better to ask them "do you have a partner?", as this allows them to confirm the language you should use to refer to their significant other. It also demonstrates that you're not making any assumptions about their sexual orientation.

When you're talking to or about someone for the first time, you may not know what gender they are, or what pronouns they use, so it's important not to assume. It's best to either use gender-neutral language (referring to the person solely by their name, or using they/them pronouns), or you can ask the person directly.

For example: You email a person called "Alex Smith". You don't know Alex's gender, or what pronouns to use. When talking about Alex, you could say: "Alex has been very helpful, and I'm grateful for their advice". Or you could email Alex directly to ask for their pronouns.

It may be strange at first, but normalising asking people's pronouns is key to changing our perceptions of gender and embracing diversity. Including your pronouns in your email signature is an easy way to demonstrate being an ally to the LGBT+ community.

Modifying your language works for sex, sexual orientation, gender and all other protected characteristics. It takes practice, and sometimes you'll make a mistake, but that's just part of the learning process! You may inadvertently mis-gender someone, incorrectly assume their sexuality or otherwise say something that doesn't reflect your values. If this happens, apologise briefly, but sincerely, and move on. For example: "I was talking to him … sorry, I was talking to her about the spreadsheet…" Over-apologising can make the situation more uncomfortable.

> "ONE OF THE BARRIERS TO IMPROVING INCLUSIVITY IS OUR IMPLICIT (OR UNCONSCIOUS) BIAS

Here are some brief examples of how to write more inclusively:

Instead of this…	Replace with this…	For this reason…
"If he or she is off sick…"	"If they are off sick…"	"They" is a non-gendered, singular pronoun, or can be used for groups of people.
"For patients in mixed-gender accommodation…"	"For patients in mixed-sex accommodation…"	This segregation is needed based on the sex of the patient, not the gender.
"The responsibilities of the Chairman are as follows…"	"The responsibilities of the Chair are as follows…"	It is best practice to avoid using gendered language wherever possible, even outside of work e.g. postal worker instead of postman, firefighter instead of fireman.

Next steps

Hopefully you are now motivated to review your local policies and procedures through the lens of making them more inclusive. You could also consider implementing the Sex, Identity, Gender & Expression form (sigehealth.com) as part of your pre-radiation exposure pregnancy checks or ensuring that your patient information posters are sufficiently inclusive.

The Clinical Imaging Board is currently in the process of re-designing the six posters they released in May 2019 to provide information to patients and their carers about the radiation used during common imaging procedures. This is as a result of a review conducted by Eva McClean, IPEM's EDI lead, Will Morton, a Clinical Scientist working for South Tyneside and Sunderland NHS Foundation Trust, and myself, into how the posters could be made more inclusive. Our proposals were accepted and the updated posters will hopefully be released later in 2022.

It's also worth looking to other professional bodies for relevant advice, as it makes sense to share best practice with colleagues working in similar fields. For example, the Society of Radiographers (SoR) has recently released inclusive pregnancy status guidelines for ionising radiation, for both diagnostic and therapeutic exposures.

EDI shouldn't be scary, or seen as something to be left to the diversity professionals. In fact, I think that Marie Skłodowska Curie said it best: "Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."

***Erin Donovan** is a Healthcare Scientist working in the Medical Physics Department at Kent and Canterbury Hospital.*

RADIATION DISTRIBUTION

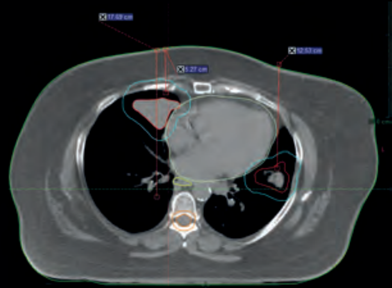
The impact of source-to-surface change

Bethan Gittos and **Joseph Purden** quantify the impact of source-to-surface change in modern lung cancer radiotherapy.

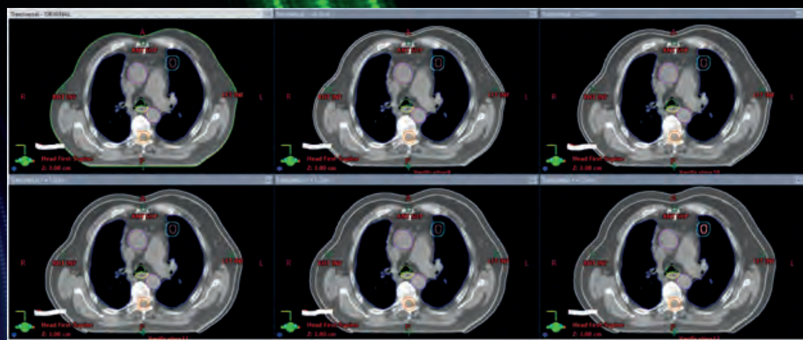
It is well known that radiation delivered continuously in a highly modulated, rotating field can lead to much higher radiotherapy success rates in lung cancer. Volumetric modulated arc therapy's (VMAT) heightened ability to tightly conform the radiation dose to the planning target volume (PTV) and avoid high radiation doses to healthy tissue and organs at risk (OARs) has meant it has, unsurprisingly, been recognised as the standard radiotherapy treatment modality in oncology centres across the UK.

However, although VMAT delivery is becoming increasingly accurate, complications can inevitably still occur with interfraction anatomical patient variations One typical example is where the body contour changes from weight loss or gain. This corresponds to variation in source-to-surface distance (SSD). Unaccounted for, these variations can lead to poorer treatment outcomes where the actual radiation dose received by the tumour is lower than the

IMAGE: GETTY



❶ Example of CT dataset modification for Patient B. This image demonstrates the remaining two volumes; the Right Lower Anterior and Left Lower Midline volumes.



❷ Example of the CT dataset modification for patient B: This image demonstrates the virtual expansion of body contour from 0.5cm to 1.5cm (left to right). Body contour is grown from the original (white), with the gap overridden with an overall blanket unit density.

planned therapeutic dose levels.

Typically, SSD measurements are documented for each treatment to assess for significant body contour changes. If a gross change is observed, this influences the decision to continue with the treatment fraction ensuring safe delivery of radiotherapy. However, thresholds for this vary between treatment centres.

The dosimetric impact of SSD changes for lung cancer VMAT is surprisingly under-researched. For lung cancer, inhomogenous thoracic tissue, increased plan complexity and closely situated OARs with tight radiation tolerances may mean SSD change would have a more profound impact than in more homogenous regions, such as the pelvis. Therefore, by quantifying the exact impact of SSD change on lung dosimetry, we can derive accurate thresholds to determine the safe delivery of radiotherapy. This can improve current guidance and provide further justification of the appropriate levels to delay and adapt treatment plans for better treatment outcomes.

Methods

Initially, the following method was used to determine possible thresholds at which the VMAT plans would deviate significantly from therapeutic planned dose levels.

Nine lung VMAT plans that met clinical criteria were created for three patient CT scans (three PTVs per patient) ❶.

For each CT dataset, the body contours were virtually expanded and reduced by 0.5cm, 0.7cm, 1.0cm, 1.2cm and 1.5cm to simulate interfraction body contour changes ❷. The VMAT plans were recalculated with these contour changes using fixed monitor units and compared.

After assessment, a standard body contour change of the derived threshold limit was applied to a randomly selected group of 40 retrospectively planned lung CT datasets to assess the reproducibility and accuracy of the results.

Results and Discussion

Effects on tumour dose

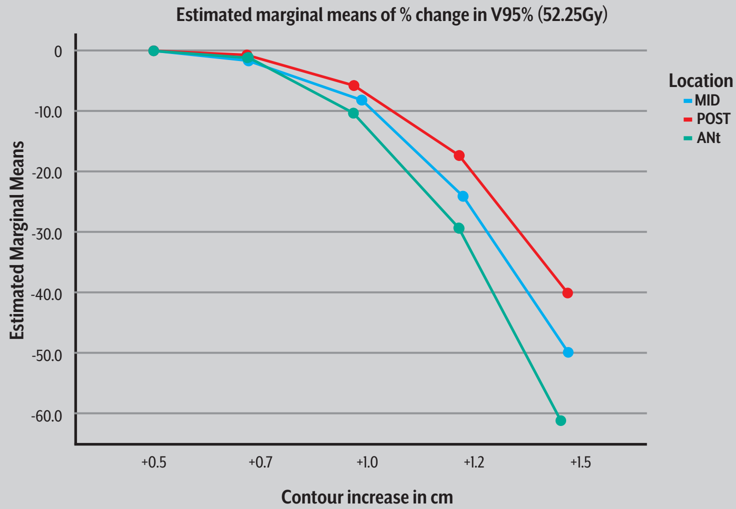
For optimal therapeutic effect, radiotherapy treatment is planned for 95% of the prescribed dose to cover 98% of the PTV. With no adjustment in monitor units, the expansion of body contour resulted in an overall decreased coverage of the PTV ❸. With an increase in depth of the PTV, radiation attenuation increases, resulting in an underdose to the tumour. The correlation for this was statistically significant, and the mean drop in PTV dose ranges from 0.4% underdose with a contour increase of 0.5cm to a more dramatic 50.9% with an increase of 1.5cm. At 1.0cm, the mean drop in coverage was 7.9% and deemed significant at this level. The impact of lesion location was also assessed, but no statistical significance between sites was found.

Visually, the volume 95% coverage crops completely from the higher density gross tumour volume ❹. With a higher density tumour volume in a low-density region, dose build-up would have decreased effectively, leading to a lack of dose to the tumour itself.

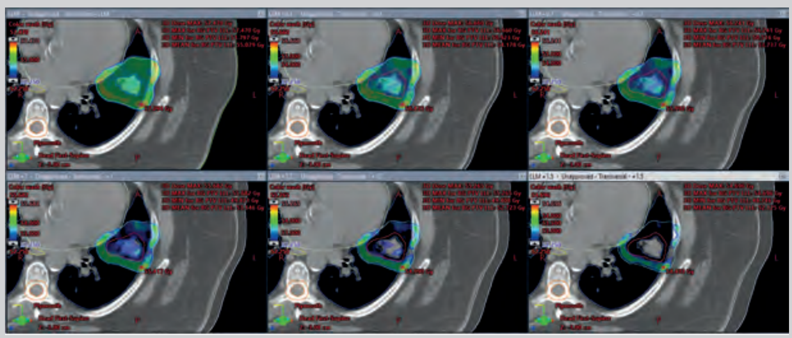
Contour increases of 0.7cm and 1.0cm were applied to a standard population, and both were deemed statistically significant ($P<0.01$). Whilst the average decrease in 95% coverage did not exceed 5.0% at 0.7cm, the average loss in coverage was 12.90% with 1.0cm ❺. Applying two potential thresholds allowed a comparison of possible thresholds offering more conviction – a 1cm contour increase would result in a significant dosimetric impact, with a likely need for modification.

Impacts on OAR doses and maximum dose (Dmax)

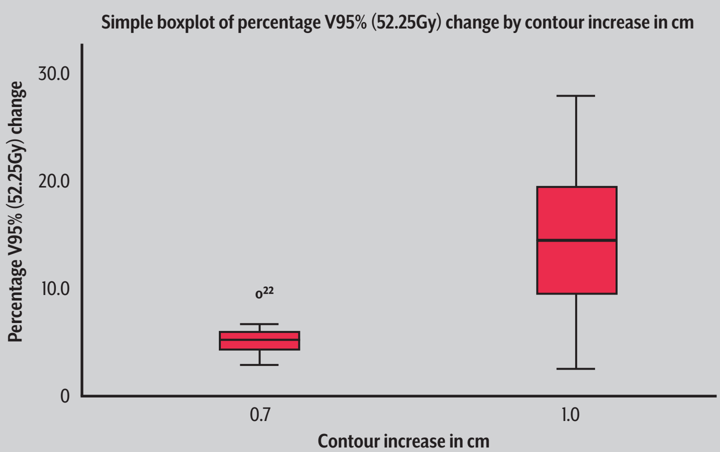
Conversely, a reduction in body contour without monitor unit adjustment increases the overall patient dose due to the decrease in radiation attenuation. Dose increase to both Dmax and OAR dose showed a significant linear correlation with contour reduction ❻. Unlike contour expansion, the results for contour reduction showed increased repeatability and lower margins for error. This indicates that dose increase with contour variation may not depend on the shape, location or size of the PTV.



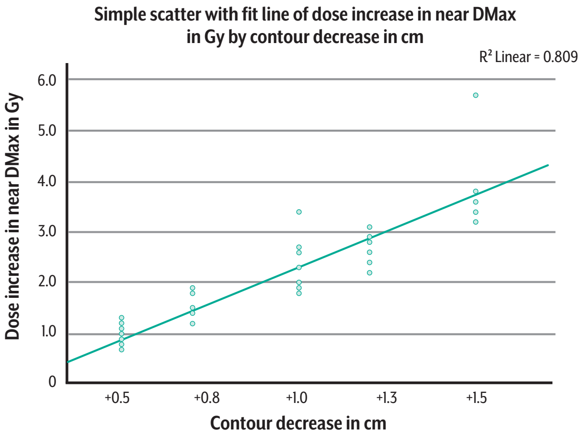
❸ Mean percentage change in PTV coverage with contour increase. A simple profile plot to demonstrate the mean percentage change in V95% (52.25Gy normalised dose) coverage for Midline (blue), Posterior (red) and Anterior (green) PTVs, with contour increase.



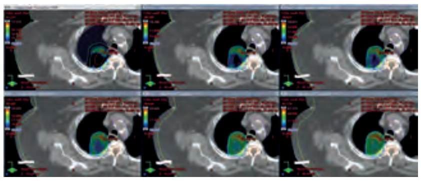
❹ Visual representation of loss of PTV coverage with contour increase on an axial image. The midline PTV (blue) and CTV (red) are shown for Patient C. The dose colour wash is displayed for 95% (52.25Gy normalised dose) and shown to change as the contour increases from 0cm (top left) to +1.5cm (bottom right).



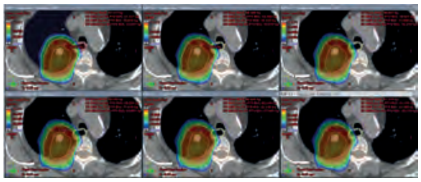
❺ A simple box plot to display the mean drop in % coverage for contour expansions of 0.7cm and 1.0cm for a larger sample size.



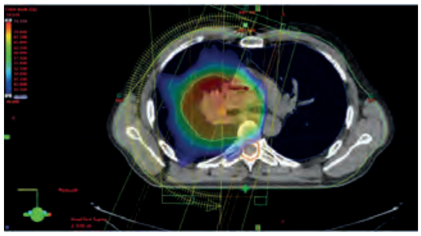
❻ The correlation between contour decrease and Dmax. A scatter graph to demonstrate the correlation between contour reduction, in cm, and the near Dmax dose increase, in Gy, for all plans. A linear regression model has been applied.



❼. Visual representation of the increase in dose with contour decrease on an axial image. The posterior PTV (blue) and CTV (red) are shown for Patient C. The dose colour wash is displayed for 100% (55.0Gy normalised dose) and shown to change as contour decreases from the original image (top left) in increments up to 1.5cm (bottom right). Dmax is also displayed and shown to increase.



❽ An example of OAR dose escalation with contour change. The posterior lesion for Patient C lies close to the vertebral canal (orange). A dose colour wash of 40Gy is displayed and shown to move closer to the vertebral canal 5mm PRV as contour decreases from the original image (top left) in increments up to 1.5cm (bottom right).



❾ An example of where OARs would be of concern: with a contour decrease of 1.2cm for this patient 40Gy is seen to overlap the vertibral canal.

It could be noted that the near maximum dose depth(DMax) had a higher impact than the maximum doses to OARs. This was also true when a contour reduction of 1cm was applied to a standard population.

The Dmax falls out of tolerance at -1.0cm for all nine plans. The likelihood of a plan becoming out of tolerance is higher if the planned near Dmax is already near tolerance. Though hotspots increase the PTV dose ❼, this goes against the prescription recommendations. Furthermore, hotspots on the edge of the PTV, present in healthy tissue, may increase normal tissue complication probability.

Associated with mean lung dose (MLD), an unforeseen increased dose to the lung with SSD could escalate the radiation-induced pneumonitis risk, especially in patients with larger PTVs. For instance, there is an indication pneumonitis risk could rise by 6% with MLDs of 10-20Gy compared to <10Gy 16 – 19. Still, tolerances for increased SSD dose effects are difficult to apply without a clear threshold.

Where OARs are abutting or overlapping the PTV, the dosimetric increase could be more prominent in a region of steep dose gradient. This could explain the increase in vertebral canal dose, for example, in ❽, by 2.4Gy with -1.5cm. This was significantly higher than the mean dose increase of 0.83Gy. Plausibly, serial organs abutting or overlapping PTVs, such as the spinal cord for posteriorly located lung tumours, would be of primary interest. A definitive tolerance would have to be assigned here to reduce the risk of myelopathy.

"THE DMAX FALLS OUT OF TOLERANCE AT -1.0CM

Dose to the vertebral canal was seen to fall above tolerance level in seven cases when contour reduction was applied to a larger sample size, all of which were posteriorly located lesions ❾.

Reflecting clinical practice

Although simulated as best as possible to reflect true contour changes that may be witnessed in clinical practice, only uniform body contour change was able to be simulated and measured in this study. Often, irregular contour changes would be seen in practice. Furthermore, although the density of contour expansion was a close match to tissue density, it did not reflect non-homogenous true body tissue. All of these factors may influence the attenuation of radiation in real-time. This is also true for contour reduction.

It is essential to consider the dosimetric impact of individual treatment fractions with SSD change when deciding whether intervention is deemed the best course of action. Although the actual dose difference per fraction appears small, if this change is seen for multiple fractions over a treatment course, the effect will be intensified. If a change is seen near the end of a fractionation schedule, it may have less impact, provided all previous fractions have been delivered correctly. A similar effect may be assumed for OAR dose with contour reduction.

Conclusion

A significant loss of PTV coverage is likely to be observed with an SSD decrease of >1cm. An intervention of a dose assessment may be recommended to further assess the next best course of action for treatment. A numerical tolerance for SSD increase is more difficult to define due to the linear relationship between contour reduction and OAR and Dmax dose increase. Still, caution should be applied for SSD increase of >0.7cm, particularly if the PTV overlaps OARs. ■

***Bethan Gittos** is a Radiotherapy Dosimetrist for Guy's and St Thomas' Foundation Trust. **Joseph Purden** is Programme Director for Medical Physics Technology at Swansea University.* *The authors would like to acknowledge N. Blackler, L. Moore and others at Plymouth Hospitals NHS Foundation Trust for the original inspiration for this project and for their support. Also F. Morton for her support and dedication towards the Radiotherapy Physics programme at Swansea University.*

Open-source project management SIGNIFICANT BENEFITS

Clinical Scientist **Robert Ross** looks at the scope and flexibility of Redmine project management software.

Following on from the article on fault logs using Redmine in the spring 2022 issue of *Scope*, and my own article on Redmine fault log development in the September 2018 *Scope*, I want to share my experience using Redmine in radiotherapy physics for over three years. While fault logs were the impetus for adopting Redmine into our infrastructure, it was immediately obvious that Redmine could bring significant benefits to other parts of our service.

Background

Having identified the benefits of moving to electronic records for fault logs, Redmine was suggested (by staff at the Royal Marsden Hospital during networking at an IPEM conference) as a viable option. Difficulties with custom electronic records typically revolve around developing databases, interfaces and accessibility. Redmine allows users to create and manage entries called "issues", the behaviour and fields within the issues are user-defined, using an interface available in a web browser. Users define the required fields and actions within the issue, using simple graphical user interface, and Redmine takes care of the graphical interface and database. It allows users to concentrate on developing their application without having to design interfaces, databases or worry about availability of software.

We installed, evaluated and deployed a turnkey installation of Redmine from Bitnami. A robust backup and recovery strategy was devised and implemented – hourly backups onto the server, with network daily backups up to 30 days old and monthly backups of both the database and any uploaded documents. Redmine was deployed onto a Windows virtual server supplied and maintained by the Trust's IT department. We logged our first genuine fault log on Redmine on 25 February 2019 and never looked back. Being in clinical use, Redmine presented itself as a solution to benefit us in other ways.

Wikis

Physicists performing quality assurance (QA) typically have notebooks, where they write down hints and tips and how to solve common issues with machines. These nuggets of useful info are often passed by word of mouth, and two notebooks may not quite agree. We used Redmine's searchable Wiki feature to create a Physics Wiki and a Computing Wiki. These allow staff to look up any issue they may encounter on a linac, from any PC (saving time traipsing up the stairs to get our notebooks). More importantly, it allows the wiki entries to be peer reviewed by the appropriate party – for example, how to clear a given interlock is reviewed by the lead engineer or lead physicist, for correctness and completeness – giving a complete and approved way to deal with common issues. Unlike a document in a quality management system (QMS), any user can create or edit a Wiki entry, and much of the material is quite short. One entry in the computing Wiki contains a list of all the active directory user groups we use for accessing various software systems, and the names of these change semifrequently. Like with fault logs, being able to quickly search for an issue and find an answer saves time – especially valuable when delays mean delayed patients and lost QA time.

> **"IT ALLOWS THE WIKI ENTRIES TO BE PEER REVIEWED BY THE APPROPRIATE PARTY**

Project Management

Redmine is designed for project management. It allows tickets – "issues" in Redmine parlance – to be displayed on a calendar or Gantt chart, along with progress monitoring and associated tickets. I used it to great benefit when project managing the commissioning of our new CT scanner last year. The simple visual indicators of progress and outstanding tasks simplified my management of the project when compared with using Excel or Outlook for the same function.

Linac clinical status

We determined that visual indicators of clinical status would be useful for our linacs. Using a single Redmine ticket ("issue") for each linac to track the clinical status (clinical / ok for clinical use / not for clinical use) provides an easy way to do this. Any user can look up the statuses – but staff on the treatment machines need an immediate visual indicator. In consultation with key stakeholders, we identified that an opaque, always-on-top traffic light indicator displayed at the top of the PC screen near the linac would be the best way forward. The indicator allows users to change the status, using their Redmine credentials to log in, with only certain user groups able to change to given statuses. The indicator programme was written in Python, using a simple REST interface-to-interface with Redmine, and is distributed as a standalone executable that runs when Windows starts. The intention is that the tracker will be updated overnight to "not for clinical use" by a server, and that accepting a run-up log will set the clinical status to "in clinical use".

Linac run-up logs

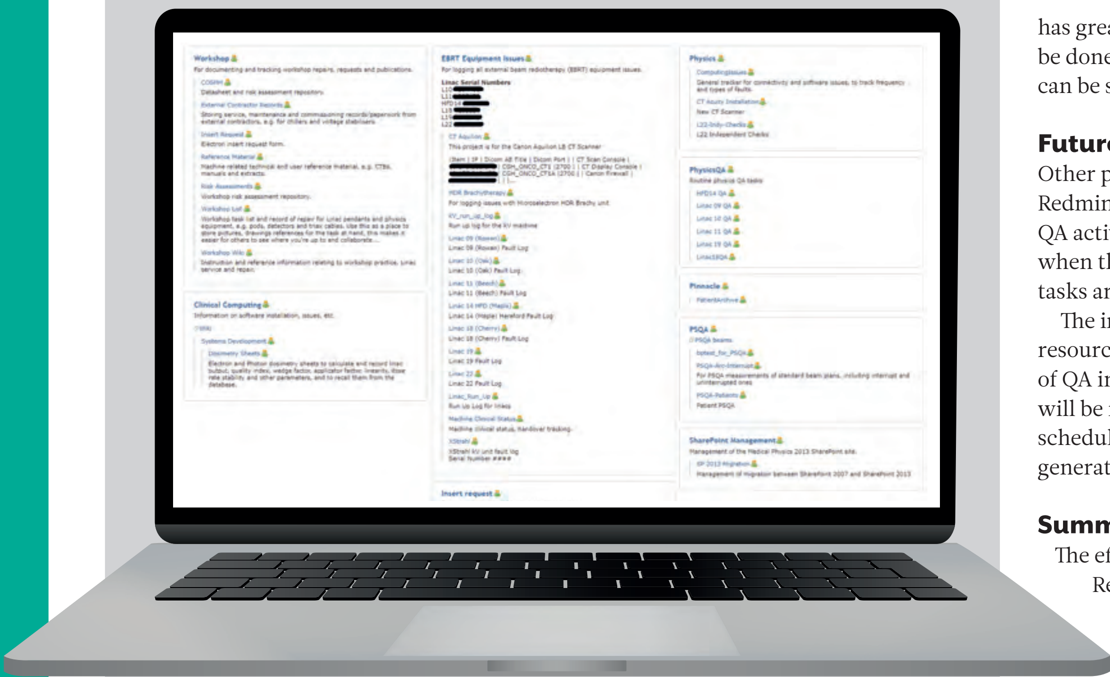
Building on the techniques in the clinical status indicator overlay, a form for data entry was easily developed in Python (using the freely available PySimpleGUI module) with data being stored in Redmine. One of the limitations of Redmine's forms is that the user has little control over layout and formatting. Plugins can assist with this, though I have chosen not to go down this route in case the plugins are not maintained or become inoperable due to upgrades of Windows or Redmine. Having Redmine and the Python scripts being independent of third party developers will minimise issues going forward.

Patient-specific QA

Fault logs are not the only records we keep – patient-specific QA (PSQA) is recorded and we identified a need to move to a new electronic record system. Rather than develop spreadsheets or MS Access databases, a tracker was designed to do this in Redmine. Entries can be made via the Redmine web interface, with the individual patient plan's progress through its PSQA pathway being recorded and updated appropriately, including results and uploaded PDFs. Redmine allows users to define stored queries (using just a few mouse clicks) and make them available to everyone, which allows the data to be easily displayed in a variety of ways – by current progress, treatment site, linac and QA date, for example. I developed scripts on our treatment planning system to populate much of the data directly from the plan into Redmine (patient demographics, treatment site, beam names and plan technique), reducing manual transcription.

Archive data

Data archives of our planning data are held on network storage. Historically,



❶ Projects page on Redmine, showing some of the various projects we are using Redmine for

we printed lists of archived patient plans as they were generated, detailing patient name, identifier, plan name and location and name of the archive file that contains the plan information. To recall an archived plan, the printed list was consulted and searched to locate the plan – with thousands of patients per year, the number of ring binders was becoming extensive. An electronic record solution was needed, but manual transcription was not an option for tens of thousands of plans. Scripting's interactivity with Redmine showed its true power – I developed a Python script that read each archive file and wrote the required data into Redmine. This was adapted into a script that is run for each new archive, so the archival record is kept up to date.

Some care is needed with the scripts – for example, to minimise the risk of duplicate archive data, my Python script maintains a separate index of files it has already populated on Redmine, which is not a problem, but the potential for duplicates needs to be considered. A great benefit of Redmine is the simple way that the backups are created and restored – I restored the live database to my local Redmine version, allowing me to test on an exact clone, keeping our clinical database pristine.

By using Redmine, our archival process has greatly improved – the archiving can be done in a single batch and the script can be scheduled to run overnight.

"ONE OF THE BIGGEST INDICATORS OF THE SUCCESS OF REDMINE IN OUR DEPARTMENT IS THE ABSENCE OF COMPLAINTS

Future work

Other projects I hope to implement on Redmine include using it to track physics QA activities, with users being emailed when they are assigned to tasks (or when tasks are changed).

The intention is to have a single stop resource to look at progress and scheduling of QA in a single, accessible location. Users will be notified by email when tasks are scheduled or changed, just as fault logs generate emails to physics and engineers.

Summary

The effort to bring in new uses for Redmine has been quite low. Python scripting to interface with Redmine has brought new dimensions to how we can interact with it: we can make custom forms and automate entry from other data sources. Automated Python-based data analysis would be simple to do, though we have not yet considered how this could benefit our department. Python forms greatly expands how we can use and interact with Redmine – though part of the benefit of Redmine is that users don't have to make forms. Code reuse and standardised approaches help reduce development overheads, while giving full control over the form designs.

Having a single location to go to for fault logs, Wiki entries, run-up logs, PSQA records, among others, also means users are familiar with the system – they know where it is and how to use it, the interface always looks the same. This minimises training, but also frustration. One of the biggest indicators of the success of Redmine in our radiotherapy department is not the number of compliments it receives, but the absence of complaints about it – it just works. And it's free.

***Robert Ross** is a Clinical Scientist at Gloucestershire Hospitals NHS Foundation Trust and Chair of IPEM's Clinical and Scientific Computing Special Interest Group (CSCSIG).*

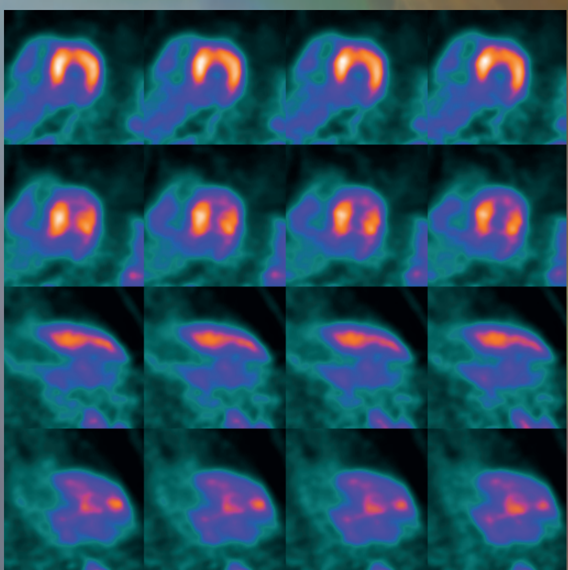
Tackling movement in cardiac PET

IN MOTION

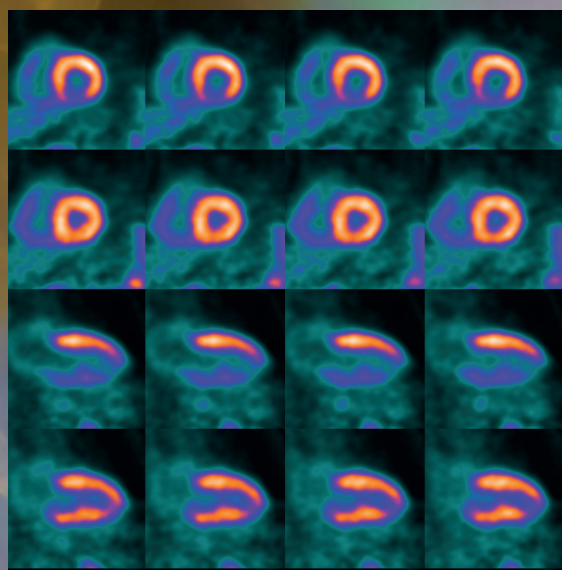
Principal Medical Physicist **Ian Armstrong** looks at issues around image quality in positron emission tomography.

Patients breathe. Patients move. Despite our best preparation and communication, these factors have been an ever-present potential for causing degradation to the quality of nuclear medicine images that are acquired over several minutes. Motion will generally cause blurring of the images but can also lead to incorrect localisation of uptake.

In myocardial perfusion imaging, commercial tools have been available to correct single photon emission computed tomography (SPECT) data from a gamma camera by shifting projections. However, positron emission tomography (PET) data are acquired volumetrically and hence motion compensation is more challenging because the correction needs to apply to the entire volume.



❶ Rubidium-82 stress and rest cardiac PET images showing the severe impact of motion.



❷ Rubidium-82 stress and rest cardiac PET images that have been corrected with the prototype DDMC algorithm.

IMAGES: GETTY

External monitoring systems have been available for several years that provide a means to try and reduce the blurring that results from respiratory motion. In oncology applications, these devices have demonstrated some positive outcomes but require additional setup time and are most effective for regular periodic breathing.

Motion degradation

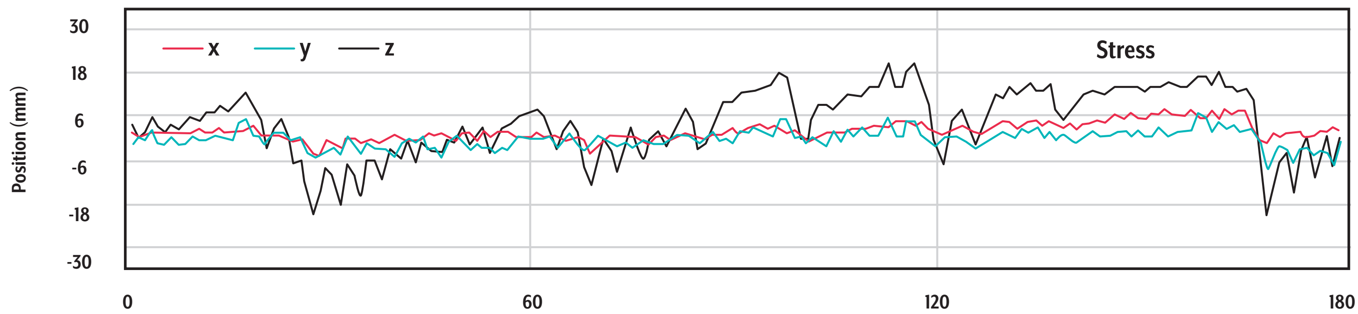
Rubidium cardiac rest-stress PET imaging has the advantage of acquiring "peak stress" images of the myocardium as the image acquisition occurs while the pharmaceutical stress agent is being infused. The downside of this is that the common unpleasant side-effects for the patient can inevitably lead to motion that is erratic and additional to the regular breathing motion. This motion can blur static perfusion images to the point that, on rare occasions, they are non-diagnostic – see ❶. Until recently, the severity and prevalence of motion degradation in cardiac PET images has been unknown. Images may have appeared slightly sub-optimal but there was no definitive way for the reporting physician to tell whether the degradation was due to motion or something else, such as high BMI patient or poor uptake. As PET scanner technology improves, the images that are produced are sharper and more defined. This means that even subtle motion can start to impact on image quality.

A new system

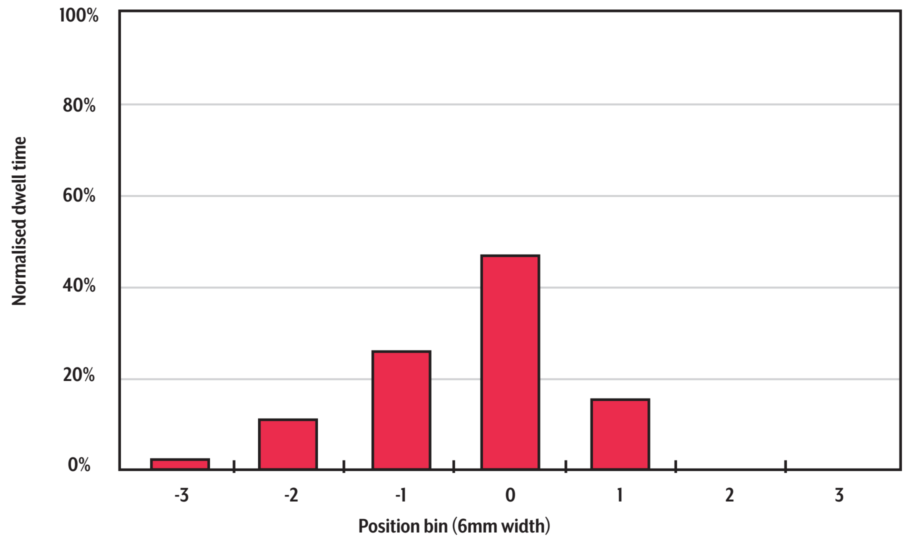
In October 2018, the new silicon photomultiplier (SiPM) PET-CT system from Siemens Healthineers, the Biograph Vision, was installed at Manchester University NHS Foundation Trust Nuclear Medicine department and was the first clinical system of its type in the world. It performs a 50:50 split of rubidium-82 cardiac PET and FDG oncology and non-oncology imaging. With motion strategies commercially available for FDG imaging, the focus was to tackle motion in cardiac PET on this new high-performance scanner.

The non-periodic motion observed in cardiac PET is not corrected by current commercial methods and hence requires a novel solution. The team at Manchester University NHS Foundation Trust have been collaborating with Siemens Healthineers for several years to

> "IMAGES MAY HAVE APPEARED SLIGHTLY SUB-OPTIMAL BUT THERE WAS NO DEFINITIVE WAY TO TELL WHETHER THE DEGRADATION WAS DUE TO MOTION



❸ Position of the heart over the three minute period that is used to produce the static perfusion images.



❹ A positional histogram extracted from a motion trace representing the portion of time that the heart dwells in each positional bin.

develop a prototype Data-Driven Motion Correction (DDMC) algorithm that is specifically aimed at cardiac PET scans. The collaboration has been extremely productive with the group publishing two papers in the *Journal of Nuclear Cardiology* and presenting findings at many international meetings.

The prototype algorithm separates the five minutes of PET data and produces 1-second images, with the heart being located in each image. Data are then shifted so that the heart is aligned on all frames and the data are reconstructed to give a motion corrected image. On page 35 ❷ shows the corrected image of the that shown in ❶. The image shows a reduction in the inferior wall on the stress images, indicating ischaemia in the right coronary artery. This patient also had coronary angiography where a stenosis of this vessel was confirmed.

Comparing images

As stated, until recently it has been difficult to appreciate exactly how many cardiac PET images have some degree of degradation due to motion. To investigate this prevalence of motion, the group compared corrected and uncorrected images in 600 blinded and randomised cases. Two medical physicists compared images and recorded whether there was no visual difference, a subtle difference or a clear visual difference between corrected and uncorrected images. They found that 58% of stress images and 33% of rest images suffered from some degree of degradation in quality due to motion and 2% of studies were non-interpretable due to severe motion degradation. This really highlights the need for a robust algorithm.

The algorithm records the displacement of the heart over the period of the image, with an example shown in ❸. This highlights the nature of motion that can be observed in cardiac PET. This positional tracking has been used to derive a metric that is used to predict the probability that images have been degraded by motion.

The group proposed a metric referred to as the dwell fraction. This is a histogram of the time that the heart occupies various spatial regions within the trace of the replacement. An example histogram is shown in ❹. It follows that, for a case with high motion, the heart will spend a small portion of time in the central position bin. It is the percentage of total time occupying this central bin that was referred to as the dwell fraction. The dwell fraction can be extracted from the raw PET data and used to predict whether a visual difference will be seen in cases after DDMC has been applied.

The collaboration has currently been expanded to assess the impact of the DDMC algorithm on additional datasets that are derived from the acquired PET data and is expected to continue for at least the next year. The aim is to provide a unified solution that can compensate for motion in all required data for cardiac PET.

Currently, data have been submitted for presentation at the American Society of Nuclear Cardiology Annual Meeting this September.

***Ian Armstrong** is Principal Medical Physicist at the Manchester University NHS Foundation Trust*

DEVELOPMENT OF STANDARDISED CLINICAL PROTOCOLS

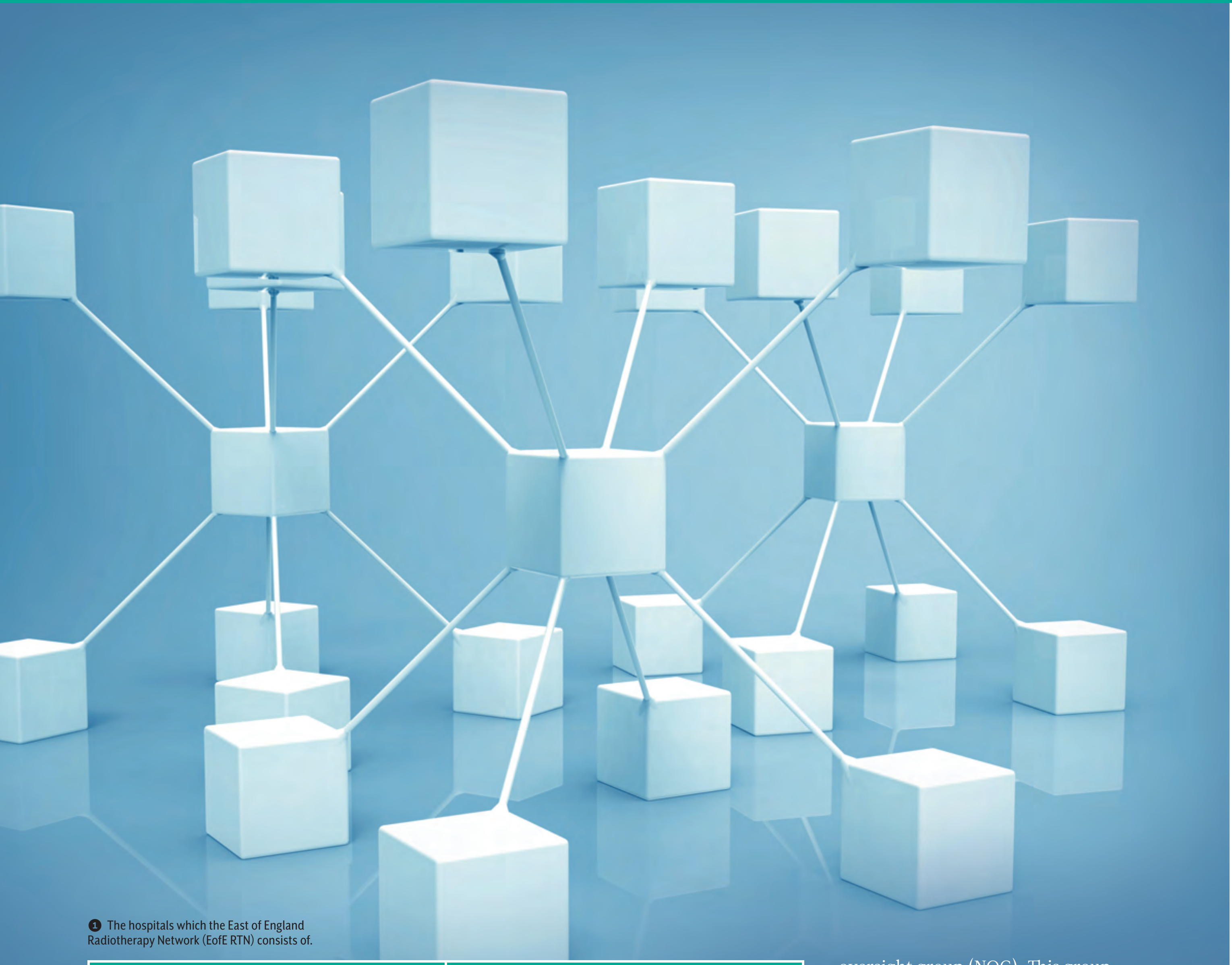
Michelle Bates, Senior Programme Manager for the East of England Radiotherapy Operational Delivery Network, guides us through the process of standardising clinical protocols.

Radiotherapy Operational Delivery Networks (ODNs) were established in April 2019 when NHS England published the service specifications for adult external beam radiotherapy as well as a specification for an ODN, which set out a network model for future delivery of radiotherapy services. Eleven radiotherapy operational delivery networks were established as a result. The five main objectives of the radiotherapy service specification are below.

The East of England Radiotherapy Network (EofE RTN) operates as an ODN and was established in October 2019 following the publication of the following Service Specifications: Adult External Beam Radiotherapy Services Delivered as Part of a Radiotherapy Network (170091S) and Operational Delivery Networks for Adult External Beam Radiotherapy Services (170092S). The EofE RTN is commissioned by Specialised Commissioning and is hosted by the Norfolk and Norwich University Hospitals NHS Foundation Trust.

The EofE RTN is supported by a network

1. **Improve the experience of care by ensuring that service users will be managed by an experienced multi-professional tumour-specific subspecialist team able to provide holistic care.**
2. **Reduce variation by adopting standardised best practice protocols thereby improving service user outcomes, including reduced mortality and morbidity from adverse side effects.**
3. **Improve access across the network to modern, advanced and innovative radiotherpy techniques, enabling more service users to benefit from cutting-edge technology and treatment.**
4. **Increase participation in research and clinical trials by 15% increase over three years in England, aiding faster development of new treatments and helping drive the development of clinical services.**
5. **Reduce variation in equipment utilisation through changing operating arrangements, clinical practice and equipment replacement; an average 15% increase in equipment utilisation for England is expected over the next three years.**



❶ The hospitals which the East of England Radiotherapy Network (EofE RTN) consists of.

HOSPITAL	TRUST
Addenbrooke's Hospital	Cambridge University Hospital NHS Foundation Trust
Colchester Hospital	East Suffolk and North Essex NHS Foundation Trust
Ipswich Hospital	East Suffolk and North Essex NHS Foundation Trust
Norfolk and Norwich University Hospital	Norfolk and Norwich University Hospitals NHS Foundation Trust
Peterborough City Hospital	North West Anglia NHS Foundation Trust
Southend University Hospital	Mid and South Essex NHS Foundation Trust

IMAGES: ISTOCK

oversight group (NOG). This group provides clinical expertise, advice, and support to the radiotherapy centres. It is an advisory group, however, constituent providers are expected to act on its agreed recommendations, which will be implemented through the providers' existing specialised services contracts with NHS England.

The EofE RTN has placed a large focus on the development of standardised network-wide protocols to reduce variation in clinical practice across the region.

Process

To develop body site-specific network-agreed protocols, a protocol development workstream has been established. The task and finish groups (TFGs) were set up with an approximate timeline ❷.

The six clinical leads who sit on the NOG were asked to nominate consultants for the position of chair of each TFG. A protocol template was developed. This was based on the protocols contained on the eviQ website – a New South Wales Government website providing a free resource of evidence-based, consensus-driven cancer treatment protocols.

The oesophagogastric protocol was the first network protocol to develop. This was chosen because there was an engaged group of consultants across the network, and a motivated chair was identified. This allowed the template to be trialled, and feedback on its format could be gained. After the chair was identified, each department was asked to nominate an appropriate consultant. Nominations were also sought for one radiographer and one physicist to join as the TFG. Prior to this meeting, the protocols from each centre were collated, and a draft protocol developed. Areas that warranted further discussion were highlighted, as well as where there were noticeable differences across departments. This draft was circulated ahead of the meeting to provide an opportunity for feedback and comment.

At the initial meeting the document content was reviewed. There was discussion about wording to ensure minimum standards were set, but where possible the protocol could be used to improve standards e.g. "where available consider 4DCT planning scan and abdominal compression, or other methods of respiratory motion control, for lower thoracic oesophageal and abdominal (gastro oesophageal junction) tumours". This wording hopefully encourages the implementation of new technology and equipment where there are benefits to the patient.

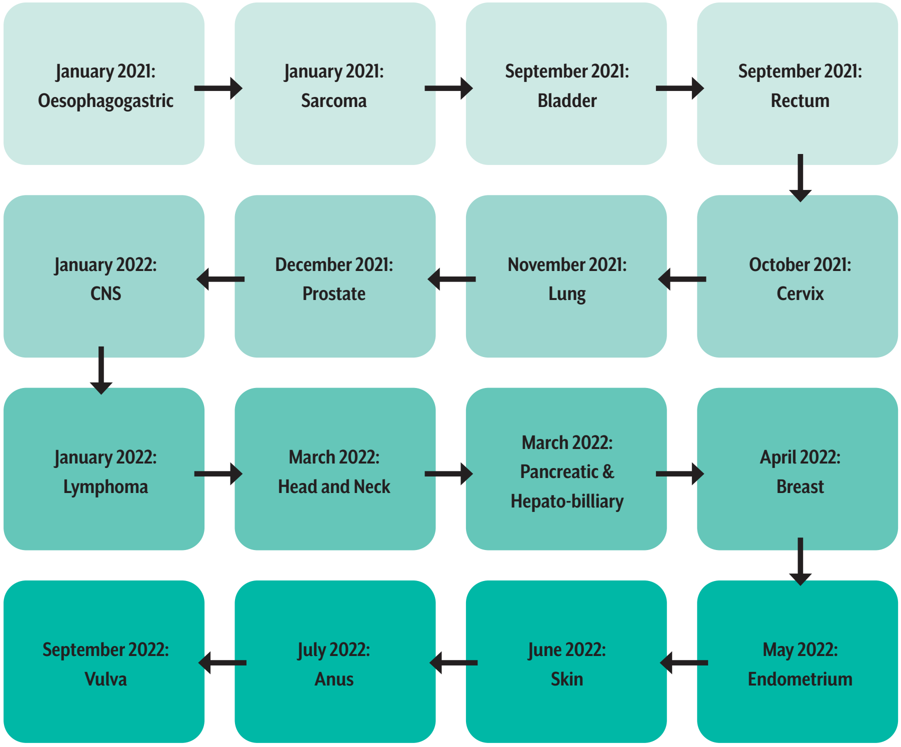
Following the meeting a second draft was circulated. This included any changes discussed during the meeting. Again, comment and feedback were requested, and a second meeting was scheduled.

During the second meeting any further comments were discussed and actioned, as appropriate. This was a shorter meeting as much of the content had already been finalised. It was agreed that the protocol would be circulated for a final round of comments before being agreed via e-mail. The final protocol was peer reviewed by a consultant from outside the network, then agreed by the TFG. Once approved it was then circulated to NOG members ready to be implemented into departmental practice.

An audit was completed six months after the protocol was released, with the aim to assess compliance with the protocol.

The results of this audit were discussed at a follow-up meeting, where the TFG also discussed any necessary improvements for the protocol. The group was asked for feedback on the protocol development process: the structure of the groups, the format of the meetings, issues with implementing the protocol locally and any areas for improvement for future protocol development groups.

The protocols will have a maximum review date of one year, although some groups have asked for six months initially. The groups will be responsible for these reviews, ensuring any updated national guidance or consensus statements are reflected within the protocol.



❷ The protocol development timeline

Insights and takeaways

Initially it was decided that the group for the protocol development needed to be kept quite small. However, we realised that it would be useful to have input from a physicist and radiographer from each department, as practice does differ across the network. When building the remaining TFGs we ensured there was a consultant, radiographer, and physicist from each department. Where necessary we also sought input from the wider multi-disciplinary team e.g., for the sarcoma protocol a physiotherapist was invited to input on pre-habilitation and rehabilitation requirements.

Some challenges around local implementation were identified. Some departments used body site specific protocols within their quality management systems, while others had documentation divided into CT/planning/on-set imaging. For those departments with body site specific protocols, implementation was reasonably straight forward as the information could be simply lifted from the network protocol and placed into the departmental protocol. For those with protocols divided by stages of the pathway it was more time consuming to identify which documentation needed updating.

To support departments with the implementation of network protocols, the NOG regularly discusses issues with implementation, and possible solutions. These meetings are held every two months, which allows us to be responsive to issues as they are raised. The TFGs are also asked regularly for feedback on any issues with the implementation process.

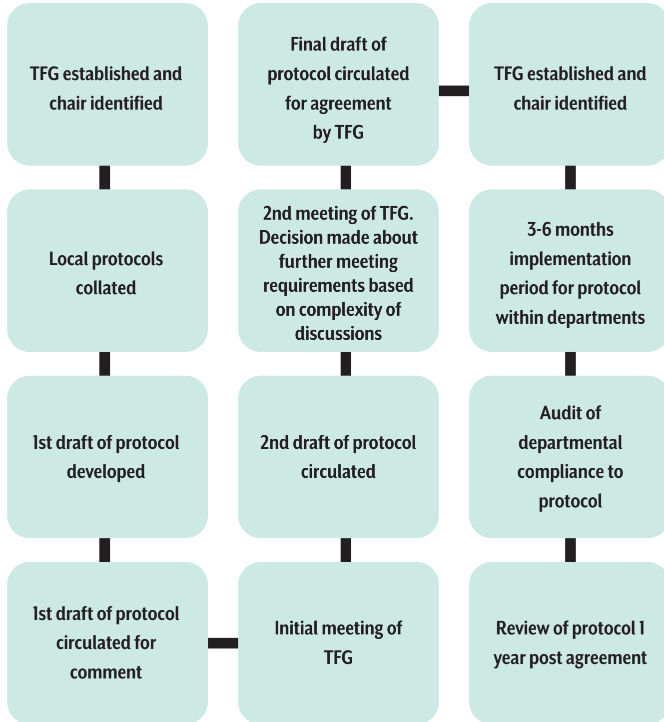
An ongoing issue we are trying to address is the lack of a network quality management system. The programme manager keeps a local database of documents, with review dates and version details. However, if a change is required to a network protocol, then the department identifying the change is required to e-mail the programme manager and chair of the group with the details of the requested change. This is then considered and actioned appropriately, if an update to the network protocol is required, a new version is circulated with an amendment history included. The network will continue to work to find a solution to this issue. The FutureNHS platform has been provided as a possible solution by NHS England and further work will be carried out to look at its functionality.

Much of the work on the protocol development to date has obviously taken place against a backdrop of the COVID-19 pandemic. This is a huge undertaking for already stretched staff and the NOG is extremely grateful for the hard work of all those who have been, or are due to be, involved.

Opportunities

The TFGs have been a useful platform to share learning and discuss ideas for collaboration. Where difficulties with peer review have been identified, links have been established to provide support. Areas for sharing of knowledge have been identified and "spin off" sessions held. For example, during the bladder protocol development there was discussion around "plan of the day" adaptive radiotherapy. This is not in use at all sites across the network, so a "plan of the day" learning session was hosted by two departments via Teams. This was a fantastic opportunity to share learning, protocols, and implementation advice.

The sarcoma TFG identified that patients undergoing treatment for sarcoma were inconsistently referred for physiotherapy, and the knowledge and expertise were not always available in their local departments.



3 The protocol development framework

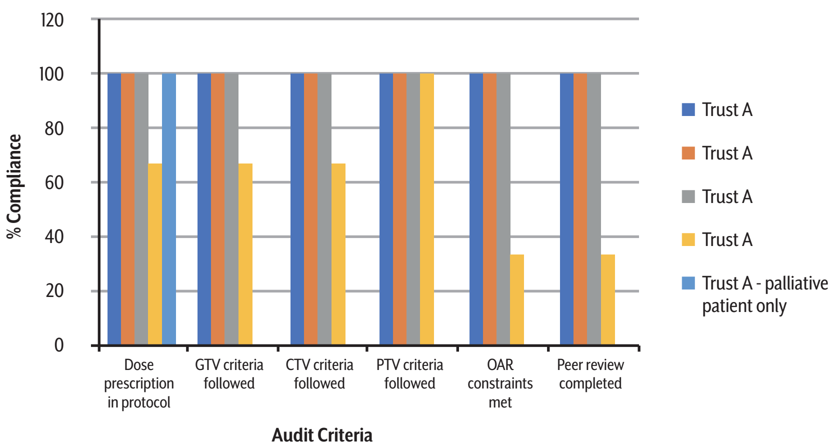
The group supported a proposal put forward to the Cancer Alliance to develop a bespoke sarcoma rehabilitation pathway that would benefit patients across the region, which was successful in receiving funding.

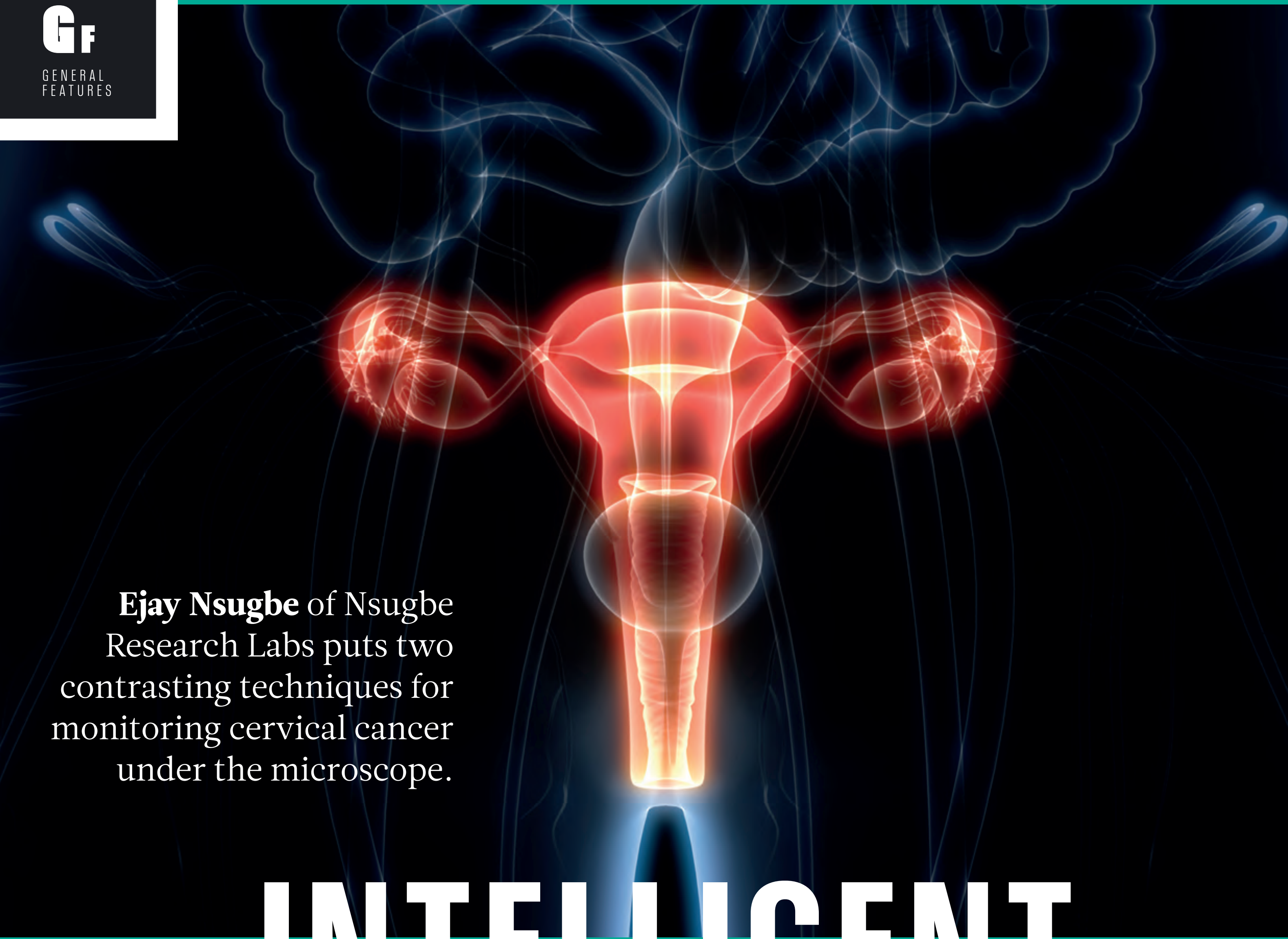
Future of the network TFGs

Firstly, there is probably a need for a name change! The term TFG was used as the task was to deliver a finalised protocol. However, these groups have evolved and there is a desire amongst most groups who have finalised a protocol to continue meeting every six months. Follow-up meetings have been scheduled as short catch ups to review the protocol, identify any areas for improvement and review any body site data or trial results that may be available that could bring about further improvements within the network.

The lung and breast groups will also be consulted during the implementation of the breast and lung metrics, once they are published. It is hoped that these groups will then continue to analyse any network data from these metrics – an implementation plan for this will be developed once the network has more information.

4 Departmental audit of compliance against the EofE RTN oesophagogastric protocol during June 2021.





Ejay Nsugbe of Nsugbe Research Labs puts two contrasting techniques for monitoring cervical cancer under the microscope.

INTELLIGENT GYNAECOLOGICAL ONCOLOGY

A cervical cancer case study

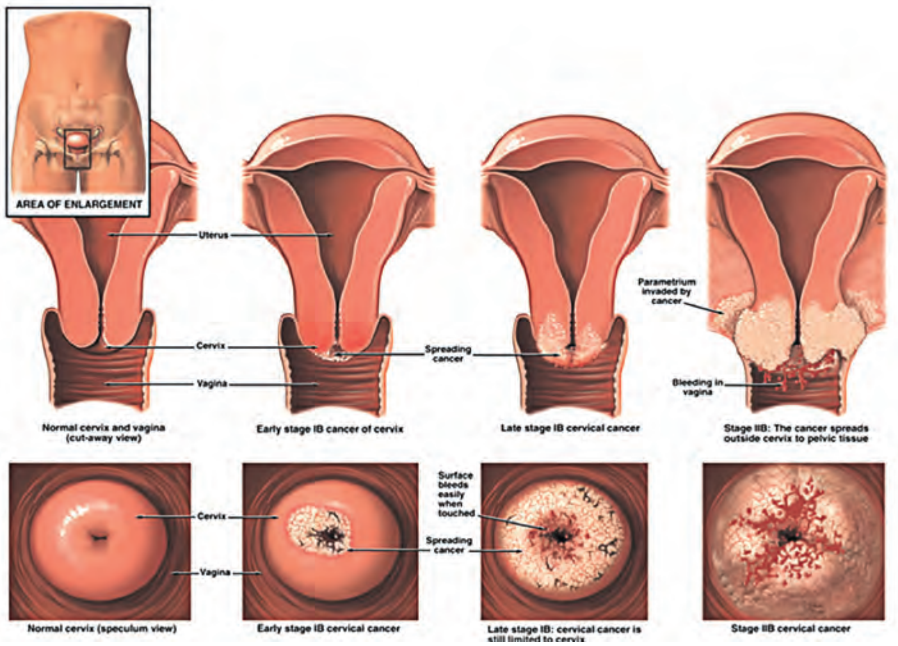
The regeneration of cells in the human body happens at a rate of 50 to 70 billion per day, during which malignant tumours can form as a sign of cancer. Cervical cancer is a major form of a female reproductive cancer, which is the third most prevalent cancer and overall the fourth leading cause of cancer related deaths. In the early stage, the symptoms of cervical cancer are strongly latent and difficult to diagnose, which has contributed towards the high mortality in developing nations due to the absence of specialist skills and accompanying diagnosis instrumentation. In the latter stages of the cancer, where the symptoms become more distinct, with characteristics of the cancer including vaginal bleeding and pelvic pain, it becomes more challenging to treat. An early diagnosis of the cancer can make the disease more treatable and improve the survival ratios.

The predominant means of diagnosis of cervical cancer continues to be based around various imaging modalities, with the ultimate short coming of this being the expertise required, alongside the high cost of the diagnostic instrumentation.

An image showing the various sub-stages of the cervical cancer stage 1B can be seen in ❶.

The application of machine learning predictive models towards cancer prediction and care is one which has seen a steady rise in the literature, although the main criticisms of those kinds of contributions revolve around issues such as the use of predictive models to produce binary outputs– i.e cancer vs no cancer – without any auxiliary information to provide further insight on the extent of the cancer, as well as a lack of insight into how the prediction models can be used in synchronism with clinical experts within a clinical setting to improve overall patient care.

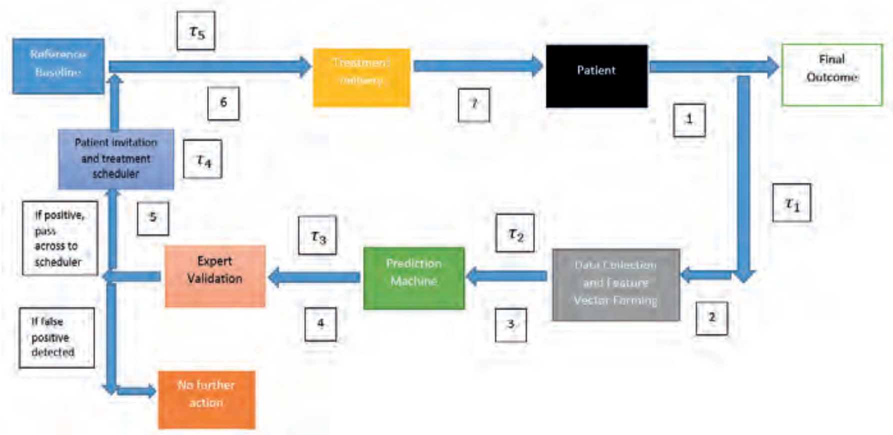
The work presented in this article represents a contribution towards a pioneering area of intelligent gynaecology where cybernetic systems are proposed to host and foster collaborations between optimised prediction machines as well as clinical experts in order to form an augmented/super intelligence platform capable of enhancing care strategies for patients within gynaecology. As part of this, an overview of the proposed cybernetic system is presented alongside details of the design of the prediction machine, which is capable of not only a binary prediction on the presence of cervical cancer, but also a prediction of the extent of the spread of the cancer using two distinct unsupervised learning-driven inference systems.



❶ A series of snapshots associated with the various sub-stages of cervical cancer 1B

Proposed cybernetic system

The concept of cybernetics can be traced back to the seminal work of the late, great Professor Norbert Wiener and is themed around a methodical steering of the state of a system towards a desired end goal. It is typically adopted as a means towards obtaining higher efficiency and better performance from a candidate system. The proposed clinical cybernetic loop can be seen in ❷, and can be summarised and discussed via the hierarchical cybernetic framework comprising of the first order cybernetics (which analyses the technical nuances of the system) and the second order cybernetic framework (which is nicknamed the "cybernetics of cybernetics"), looking at the end-to-end functionality of the proposed loop under the influence of a feedback element.



❷ Proposed cybernetic system-

First order cybernetic analysis: this section looks at a summary of the sub-component within the cybernetic loop alongside their interactions.

System/patient: represents a female in the age range of 25-60 who would be eligible for cervical screening

Data collection and feature vector forming: for this study, this involves the collection of various information around some features that have been clinically proven to contribute towards the presence of cervical cancer and can be seen below as follows: age, number of sexual partners, age at first sexual intercourse, smoker, use of hormonal contraceptives, use of intrauterine devices, cervical intraepithelial neoplasia and human papillomavirus.

Prediction machine: given a feature vector from a patient, the role of the prediction machine is to make a prediction on what patients potentially have cancer and then subsequently make an inference on what stage and extent the cancer is, given a positive prediction.

Expert validation: at this stage, human intervention kicks in and plays the role of an optimal state tracker, where it is anticipated that the clinician would be poised towards picking up potential false positives and would be supported by expert knowledge and knowledge of patient medical health record.

Patient invitation and treatment scheduler: this is an intelligence-driven algorithm that sorts and prioritises the scheduling of treatments based on the estimated severity of the cancer of the cervix. Algorithms that can potentially underpin this stage include the use of optimal control and metaheuristically-driven genetic algorithm.

Treatment delivery: this stage involves the administration of medication and associated treatment therapies and is envisaged to be carried out by a multidisciplinary team where the potential treatment therapies include surgery, radiotherapy, chemotherapy and immunotherapy.

From the perspective of second order cybernetics, the inclusion of a prediction machine strengthens the feedback pathway of the proposed loop and serves as an additional layer of decision support, the presence of which can help raise the efficiency of diagnosis with regard to predicting presence which can make for better care strategies for patients where softer cancer treatment options can be utilised. The treatment scheduler can allow for a greater level of clinical efficiency where, once the prediction from the prediction machine has been validated by the clinician, the treatment scheduler can begin to prioritise patient invitations to the clinic for treatment.

Design of the prediction machine: the data used as part of the design of the prediction machine was obtained from the University of California at Irvine (UCI) database and was collected from the Hospital Universitario de Caracas in Caracas, Venezuela. The dataset comprised of up to 28 features that have been seen to medically correlate towards HPV and cervical cancer, alongside the biopsy grading, which served as the labels for the samples within the dataset. After data cleansing and pre-processing, a sum total of samples from 650+ patients were utilised for the modelling exercises that followed, with the SMOTE algorithm further used for class balancing purposes.

As part of the pre-processing, the principal component analysis (PCA)

Probability value	Potential cancer stage
0.4–0.5	Early stage
0.5–0.7	Medium stage
0.7+	Advanced stage

3 Probability values and associated potential cancer stage

4 Results of unsupervised and supervised learning for the probabilistic method

	Acc (%)	Sens (%)	Spec (%)	AUC (%)
GMM-DT	83.5±1.7	86.9±2.5	80±3.1	83.8±2.6
GMM-LSVM	86.4±1.2	80.2±0.8	88.1±4.4	84.5±2.5

Acc: Accuracy, Sens: Sensitivity, Spec: Specificity, AUC: Area under the curve

5 Results of unsupervised and supervised learning for the fuzziness method

	Acc (%)	Sens (%)	Spec (%)	AUC (%)
FCM-DT	89.1±0.3	86.7±0.7	85.5±1.0	85.7±0.7
FCM-LSVM	91.5±0	96.1±0.3	95.1±2.3	95.2±1.0

Acc: Accuracy, Sens: Sensitivity, Spec: Specificity, AUC: Area under the curve

"A GENERALLY HIGH ACCURACY WAS RECORDED FOR THE FCM SUPERVISED LEARNING EXERCISE OF UP TO 90%

was used as a means of an unsupervised embedding and dimensionality reduction tool, where the first five principal components of the data, which accounted for 90% of the variability, were retained.

Two unsupervised learning models were applied and contrasted as part of this study, and are described as follows:

1 **Probabilistic method:** the Gaussian mixture model (GMM) is a probabilistically driven means towards clustering of data where a canonical model for the GMM is one which can be said to involve a mixture of Gaussians of which each one is parametrised by its mean and covariance, where the number of clusters were selected as two from prior knowledge – i.e clustering of patients with and without cancer.

2 **Fuzziness method:** this was done using the fuzzy c-means (FCM) method – an unsupervised clustering method capable of grouping samples into distinct clusters with respect to an objective function. FCM is based on assigning memberships to samples that are close to the value of 1, therein implying high similarity, while on the contrary membership values close to 0 indicate minimal similarity and compatibility between a sample and candidate cluster. In this work, the fuzzy partition exponent was selected to be 2, whilst the membership function criteria to qualify for either group was 0.6.

The unsupervised learning models were used in tandem with supervised learning models, a list of which follows:

1 **Decision tree (DT):** a non-parametric model that utilises Boolean logic-based sorting towards partitioning data samples into groups and is also termed as a white box modelling approach

2 **Support vector machine (SVM):** is an iterative classifier whose architecture is based around the instillation of class boundaries in a higher dimensional subspace using a subset of the dataset known as support vectors with the assumption that clusters have a greater level of separability in higher dimensional space. The linear version of the SVM was used in the study (LSVM).

The validation method for the classification models was the K-fold cross validation, where K=10, and the data split was in the order of 80% for training and 20% for validation.

Results

Probabilistic cancer prediction: for this model, the probability scores from the GMM partitioning was used to create further labels for the samples defined by their uncertainty, in order to create an approach which the stage of the cervical cancer can be inferred from as shown in ❸. This inference approach allows for a first-stage estimation for the stage of cancer given a positive prediction, without the need for an invasive examination. The GMM results showed a cluster mixture ratio of 0.30:0.69 (cancer: no cancer), displaying a mild bias towards cluster 2, the GMM labels were sorted and used as labels for a subsequent supervised learning exercise, the results of which can be seen in ❹.

The results in ❹ show a generally high accuracy in the region of 80%+ where it can also be seen that the LSVM slightly outperforms the DT, highlighting the strength of kernel-based learners for these kinds of problems.

Fuzziness based cancer prediction: for this case, the soft clustering options of the FCM clustering algorithm was utilised as part of this algorithm in order to identify data samples that fell below the defined threshold and could be indicative of a latent and early stage cervical cancer. Where membership function thresholds were selected to be 0.6, therein ensuring that only data samples whose membership values were higher than that of a coin toss, (0.5/0.5) were assigned in specific clusters. The accuracy of the FCM was seen to be 69%, which was calculated as the difference between the expected number of samples in a cluster and actual clustered points, expressed as a percentage. Following this, the resulting labelled samples were fed into the candidate supervised learning algorithms.

The results from the learning exercise are shown in ❺. Generally high accuracy was recorded for the FCM-supervised learning exercise of up to 90%, dependent on the classifier used. Although the increase in prediction accuracy compared with the previous method is due to the reduced classes for this particular case i.e early stage cancer vs ongoing cancer.

Discussion and Conclusion

In this study, two contrasting means towards the monitoring of the extent of cervical cancer have been proposed where probabilistic learning and fuzziness-based methods have been investigated. Where in the case of the probabilistic learner levels of the cancer were inferred using probabilistic scoring, in the case of the FCM, the fuzziness membership were used to estimate likely patients who are in the early stage of the cancer. In addition, a clinical cybernetic system was proposed to host the prediction machine while also enabling for a human-machine decision support platform for enhanced patient care. Where the proposed cybernetic system can enable in the long run for a more streamlined means towards the screening and diagnosis using mobile-based platforms could also be used as part of its implementation. From a resourcing perspective, the proposed system would favour resource-constrained settings due to the cost saving aspects of its operability, when compared with clinical routine testing. It would inevitably carry a great appeal for the developing nations which have a high degree of mortality for cervical cancer – although further simulation based work is required for the testing, iteration and validation of the performance of the proposed cybernetic system. ○

The all new IPEM WEBSITE GOES LIVE

In late March the Institute of Physics and Engineering in Medicine (IPEM) launched an entirely new website, designed to support its 5000 members as well as to inform and engage stakeholders, partners and the wider public.

A modern, responsive platform, www.ipem.ac.uk is designed to serve the needs of users – and particularly IPEM members – much more effectively. As a hub of useful, dynamic and increasingly interactive content, it will underpin growth in membership, offering professional development opportunities for members, a sense of community and a place to demonstrate leadership and advocacy on the key issues impacting healthcare science.

Background

The project began in 2021 with the launch of the "IPEM 2025" organisational strategy, which recognised the clear need to upgrade the existing website with a 21st century platform that could address the needs of a respected, diverse and international membership organisation on a mission to improve health through physics and engineering in medicine.

Process

With support from specialist consultants, the IPEM team worked up detailed requirements for a new public-facing website in concert with a number of members and other stakeholders across the organisation, via a series of online workshops. The aim was to understand what the new site would need to deliver whilst being mindful of some of IPEM's key strategic objectives over the next five years, including:

- Growth in both membership and engagement with members
- Growth in professionalism through learning and development
- Growth in impact as an organisation, both as an advocate for our members and for physics and engineering in medicine.

These objectives helped guide the workshops, in particular when discussing the challenges faced by the incumbent website, which suffered from not being optimised for tablet or mobile, limited navigation and low quality search functionality, as well as not having the capacity to support possible future technology projects, such as a new learning management system. The process culminated in an in-depth analysis of the issues, the detailed specifications required for a new site and an agreed approach to testing before going out to tender for developers.

Major changes

The former site was not optimised for phone or tablet users, which makes up a growing proportion of traffic, nor was it readily searchable or shareable via social media channels, limiting its reach at source. It also did not reflect the new IPEM brand, which launched in 2021 and is optimised for digital use. The new site does all of this and more (see column, right, for the key areas of improvement).

One of the big challenges was in trying to present much of IPEM's content differently in a digital age, particularly where large amounts of historic content exists as PDFs rather than dynamic HTML pages, which are more interactive, accessible, and are better able to utilise multimedia elements. It will take time, but converting and enhancing a proportion of pertinent PDF content will go some way towards meeting IPEM's accessibility and engagement aims.

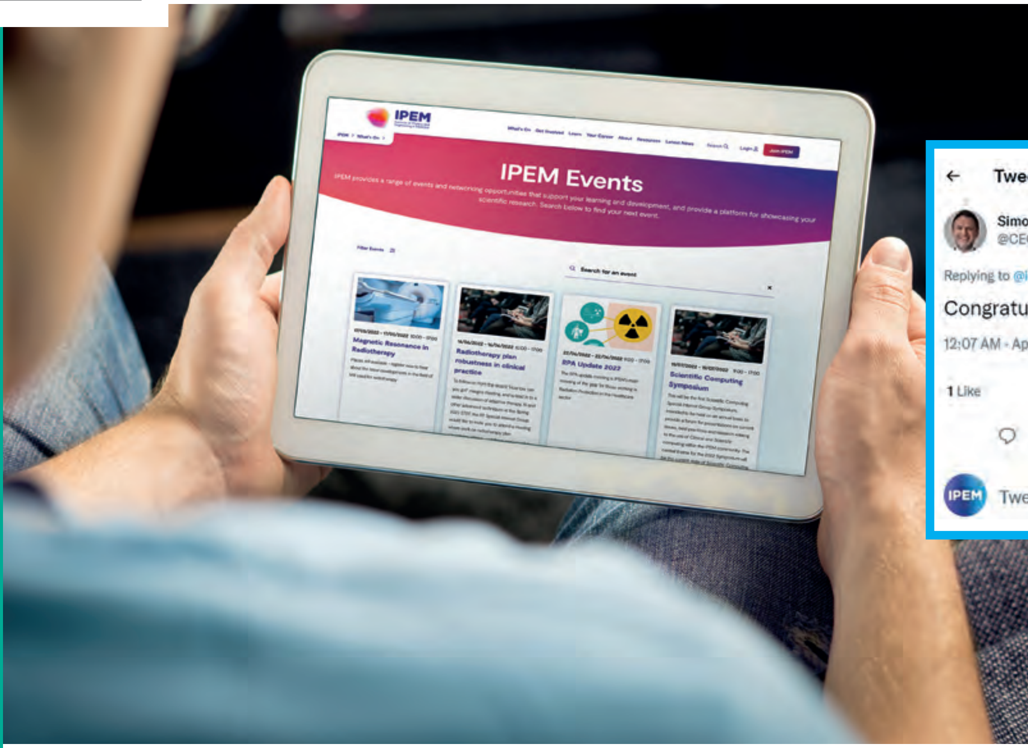
Utilising HTML content will also enable the tagging of content to aid sharing across and beyond the site, as well as facilitating the surfacing of "related content" to ensure that site users are offered relevant options to continue their journey through the site.

The new site also offers the opportunity for search to be enhanced through additional metadata to help both in-site search, and off-site via Google (or other search engines). This will encourage members to have greater confidence in using the built-in search function, and already visitor search statistics show encouraging growth.

Events are a key offering of any membership organisation. As such, ensuring that events promoted online are up to date and are presented in an aesthetically pleasing way is another key output of the new website.

The journals and e-Books offered to IPEM members and accessed through the website are major member benefits, and IPEM has

FIVE KEY WEBSITE IMPROVEMENTS



partnered with organisations such as IOP Publishing and Elsevier to increase the quantity and quality of available content. The new website presents these offerings in a clear and attractive way that highlights their importance.

The website is one of the first projects to focus on "process automation" to improve the experience for both members and internal process owners. For the site this means enhancing the process of adding content and sending data to the customer relationship management (CRM) system. This is important as it means that the new website has been built in a flexible way that allows new CRM integration – as and when required - to be achieved with minimal additional development effort.

The new content management system (CMS) behind the site helps to manage content production workflow, to better ensure that content remains up to date, findable, useful to members and others, and supportive of IPEM's strategic aims.

Whilst the new site has been defined by the requirements elicited in the discovery workshops, further variations and feature improvements will be defined by understanding real user behaviour now the site is live – interrogating user analytics and viewing activity to optimise key user journeys through the website will allow the product to continue to evolve.

The website has been delivered on time, and whilst still a work in progress, addresses many of the needs identified as crucial by IPEM members.

A dynamic platform

Dr Robert Farley, IPEM's President said: "I am delighted with the new website, which will transform the user experience. It gives us a modern, fit-for-purpose digital platform to help us deliver our strategy as we grow as an organisation.

"I'd like to thank all those members, volunteers, staff and stakeholders who worked with us across a series of workshops to identify the key issues with the old site, which we then focused on tackling in the new platform.

"It's an ongoing, living project of course, like any good website, so we will continue to refine it as we receive feedback, but we are delighted to have gone live and look forward to sharing as widely as possible."

Paul Barrett, IPEM's Head of Communications said: "We have worked to deliver a platform which is accessible to key industry standards, much more searchable, easily shareable via social media and other channels, more personalised, optimised for all devices, and ultimately offers a flexible and attractive showcase to share what our members do and why they play such a crucial role in delivering modern healthcare.

"Of course, the real work starts now! Whilst we have launched the site, it will only be as good and as useful as the content it shares, and we continue to work on improving our offer. With any such project there are teething problems, and we welcome all feedback on areas to improve. Overall we are pleased to deliver a key facet of our IPEM 2025 strategy – a dynamic platform which will be of great benefit to our members and a source of reliable, relatable, well delivered content to our wider audiences."

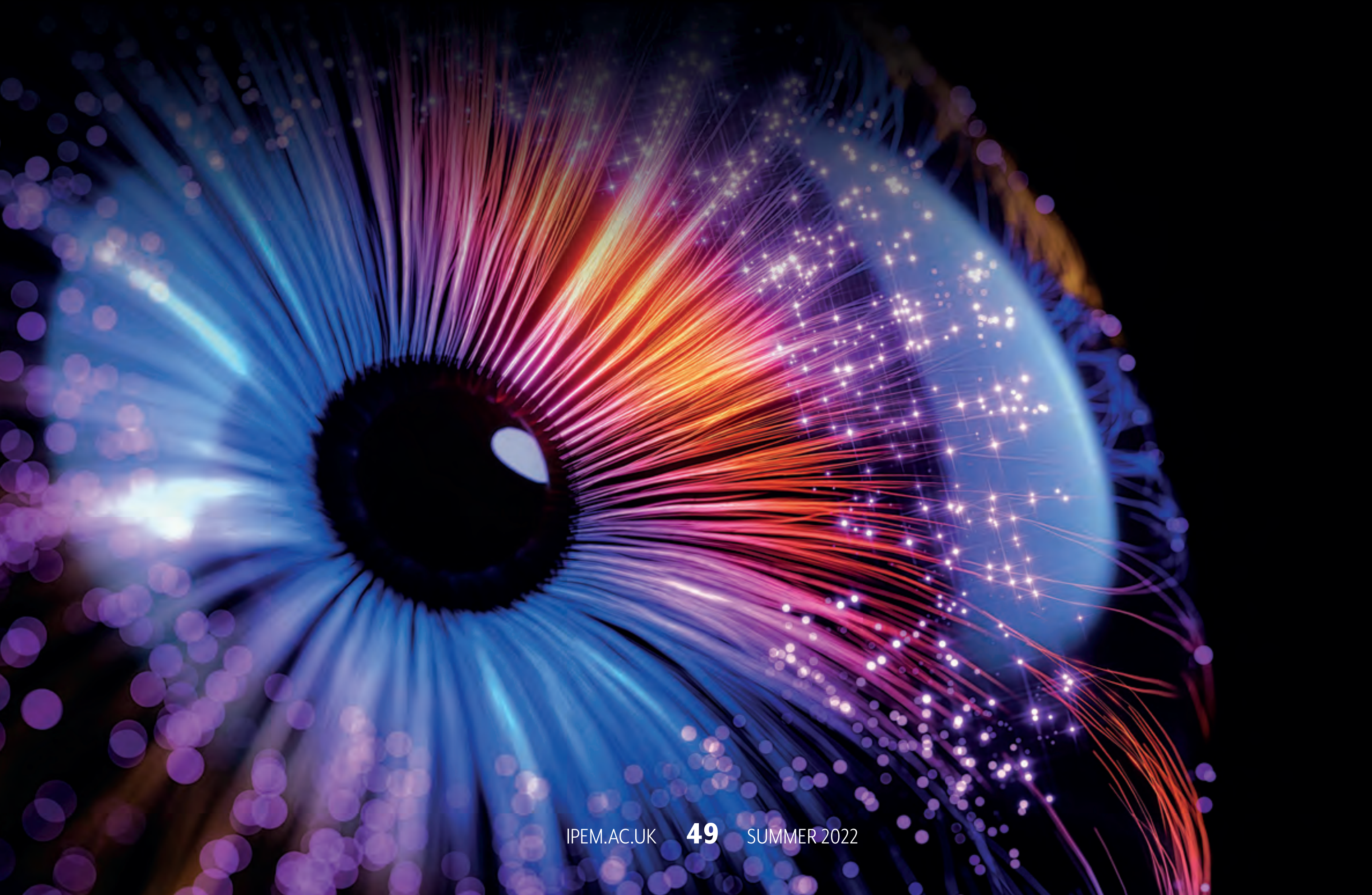
"THE WEBSITE ADDRESSES MANY OF THE NEEDS IDENTIFIED AS CRUCIAL BY IPEM MEMBERS

*If you have any feedback you would like to give on the website, please contact **communications@ipem.ac.uk**. Visit the website at **www.ipem.ac.uk***

Senior Clinical Scientist in Nuclear Medicine **Jan Walukiewicz** reports back on the key messages from an IPEM event.

Cutting edge computations in NUCLEAR MEDICINE

IMAGE: ISTOCK



Cutting Edge Computations in Nuclear Medicine commenced on 26 January 2022 with nine talks from a diverse range of international speakers. There were forays into Poisson statistics, the mathematical description of nuclear decay, as well as introductions to more novel radiomic and artificial intelligence (AI) applications. Regardless of your career stage or background, there was something intriguing and novel for all. What unified every talk was the same harmonising mantra – nuclear medicine is a computationally intensive modality that will see continued clinical benefit from advances in software and computational techniques.

Kinetic modelling: present and future – Beverley Holman

Standardised uptake value (SUV) in positron emission tomography (PET) is a semi-quantitative parameter that provides useful clinical information at a single time point. However, kinetic modelling produces multiple parameters that can be used to further characterise biological and chemical changes in the body over time. Beverley introduced [^{18}F]FDG as an example compartmental model; the current workhorse of PET services. The parameters of this irreversible two-tissue compartment model were discussed, including their associated assumptions. Beverley provided several examples from literature of kinetic modelling providing useful additional clinical information.

Dynamic imaging is required for kinetic modelling, which has several drawbacks clinically, such as increased scanning times and complicated analysis. However, the current advancements in technology could counteract the long scanning times with the development of total-body PET scanners. With the huge increase in sensitivity achievable with these scanners, Beverley presented examples of 2 second and 0.1 second dynamic frames to highlight the capability and future potential of kinetic modelling in the clinic.

Quantitative SPECT – John Dickson

John introduced the concept of absolute quantitative single photon emission computed tomography (SPECT) after recapping the relative quantification of myocardial perfusion and dopamine active transporter (DaT) imaging, as well as the algebraic techniques of [^{99m}Tc]Tc-HMPAO. SUV has found value in PET, so perhaps there is similar value in SPECT?

We were reminded that absolute SPECT quantification requires similar corrections to that of PET: attenuation, scatter, resolution and a sensitivity calibration. The considerations required when performing absolute quantitative SPECT were presented as a logical narrative, starting with the patient preparation and ending with the required corrections, discussing radionuclide calibrators, acquisition parameters, and reconstruction along the way.

The pitfalls of quantitative SPECT were introduced, including that reconstruction algorithms are typically

DEVELOPMENTS IN NUCLEAR MEDICINE

"Nuclear medicine is underpinned by a variety of mathematical techniques, implemented across a range of software. The ever-advancing computational power at our disposal has allowed computationally expensive methods to be used routinely, putting the mathematics to good use in image reconstruction, accurate scatter correction, or image analysis, to name a few. New developments, such as artificial intelligence (or machine learning) have an extraordinary potential to contribute to solutions across a raft of problems in nuclear medicine. Given the importance and breadth of these mathematical techniques, combined with advances in the nuclear medicine practices that they support, the IPEM Nuclear Medicine Special Interest Group sought to pull together a range of experts to deliver a one-day programme that would provide valuable education and insights in this area. The aim was for the programme to be of interest to a large part of the nuclear medicine community, sharing knowledge of techniques applied now or in the future. My sincere thanks go to Dr Sarah McQuaid, who was the programme lead and chaired the meeting, as well as to the invited speakers for delivery of such a high-quality, fascinating programme. I am also appreciative of this review of the event, which was kindly provided by Jan Walukiewicz."

~ Matthew Walker PhD; IPEM Nuclear Medicine SIG.

IMAGE: ISTOCK

optimised for beautification, not accuracy. Ultimately, harmonisation of absolute quantitative SPECT is required in order to further utilise this perhaps underutilised technique.

Poisson resampling techniques – Gregory James

Resampling techniques are integral for optimisation in nuclear medicine – assessing the possibility of reducing activity and increasing scan speeds. Gregory familiarised us with the fundamentals of Poisson resampling, which allows for retrospective simulation of reduced count images by binomially sampling the raw pixel counts. This was elegantly explained through flowcharts and imagery and followed the old adage – a picture says a thousand words. The validation techniques of Poisson resampling were presented, including the necessity for using the correct statistical analysis. In particular, care should be taken when comparing resampled data to equivalent real data at low count rates. This is due to the Poisson distribution of counts tending towards a normal distribution at high count densities.

The key take-home, which Gregory assiduously stated, is that resampling can only be performed on raw data. Data processing destroys the underlying Poisson noise in the raw data and, in general, processed data should not be Poisson resampled.

Developing bespoke software – Robert Ross

Software is created when a set of instructions are implemented to operate a computer. Programming is a skill that most physicists who listened to Robert's talk will possess, and is an integral aspect of software creation. It is important to appreciate that programming and creating software are distinctively different skillsets. Furthermore, consideration of whether software is a medical device was discussed with useful flowchart examples from the Medicines and Healthcare products Regulatory Agency (MHRA). The simplest option is to buy software "off the shelf" or employ a software engineer to develop applications. Often, due to funding, this is not possible and it is left to in-house non-specialists.

The ideas behind implementing a quality management system and embedding what is known as the "software lifecycle" were introduced. Every step of the software lifecycle should be documented, starting with the analysis of the software requirements to the final decommissioning. This would certainly appear to be a daunting task to a non-expert physicist but guidance from IPEM, the MHRA, and articles within *Scope* are available.

An added regulatory complication is that Great Britain is currently working under the Medical Device Directive, which does not include anything on in-house manufacture and use, whereas Northern Ireland is working under the EU Medical Device regulations.

Radiomics in nuclear medicine – Irène Buvat

Irène quickly got the audience on side by stating that nuclear medicine yields beautiful images. However, radiomics can see into the beauty of these images to extract quantitative information beyond that observable with the naked eye – which Irène may argue is even more beautiful. Radiomics takes a region of interest within an image and extracts radiomic features. These features can be split into two groups; engineered features that are defined independently of the data and deep features that are defined from the data by convolution neural networks (CNNs). An engineered radiomic feature familiar to us is SUV. This was reassuring to hear, as radiomic features do not have to be complicated to be useful.

The sheer number of potential features in a "radiome" – the radiomic equivalent of a genome – can result in very complex models. To generalise these models they need to be understood. Irène provided examples of the "Clever Hans" effect appearing in literature, where complicated models made the right decisions for the wrong reasons. Perhaps one of the main issues with radiomics as a state-of-the-art technique is that few models created have been externally validated. This is a major stumbling block as radiomic features are often dependent on image quality, resulting in scanner- and centre-specific models that cannot be generalised. Inter-centre harmonisation, a technique nuclear medicine departments are well accustomed to, is one potential solution.

Despite the difficulties of applying radiomic models, radiomics offers an exciting next step for nuclear medicine

> "THE SHEER NUMBER OF POTENTIAL FEATURES IN A "RADIOME" CAN RESULT IN VERY COMPLEX MODELS

and patient care. Literature apt for a nuclear medicine-based talk was presented demonstrating the appeal of radiomics, with perhaps the most useful aspect being that radiomics can answer a specific clinical need or question.

Segmentation methods in nuclear medicine – Dimitris Visvikis

Segmentation is a key processing step in many of the previously presented talks, as quantitative measurements are dependent on the defined functional volume of interest. These volumes are inherently difficult to define due to image noise, partial volume effects, voxel size and tumour heterogeneity. Dimitris presented the evidence for moving away from fixed thresholding techniques, which are still widely used clinically, to statistical and deep learning algorithms.

Although fixed thresholding for segmenting tumour volumes does not suffer from repeatability issues, it is highly sensitive to tumour size and has poor reproducibility. A simple improvement is to use adaptive thresholding techniques. Statistical methods, such as the Fuzzy Locally Adaptive Bayesian (FLAB) method, provides further robustness and better reproducibility. The next step is the move to CNNs which are not widely used clinically. The evidence suggests that CNNs are able to further improve functional volume segmentation, with the example of cervical tumour volumes automatically delineated despite the presence of normal physiological uptake in the bladder.

> **"ACCURATE TUMOUR VOLUME ENABLED BETTER PATIENT STRATIFICATION AND MANAGEMENT**

How will improvements in functional tumour volume segmentation translate to advances in clinical care? An example is oesophageal tumour size, which is a prognostic factor for survival and therapy response. Accurate tumour volume was found to enable better patient stratification and management. Furthermore, tumour volume segmentation is currently an important part of the radiomics pipeline, and accurate volume segmentation has been shown to improve doses to target tissue in radiotherapy without significantly increasing dose to organs at risk.

Internal dosimetry for molecular radiotherapy – Jonathan Gear

Jonathan's talk presented the fundamentals of internal dosimetry, and began with an overview to the steps required in the molecular radiotherapy dosimetry chain. The uncertainties that propagate through the dosimetry chain were focussed on, such as volume uncertainty due to operator variability and data quality. It was also shown that SPECT recovery curves require larger activity volumes than are typically used to fully characterise the recovery curve for higher energy emitting isotopes. Current National Electrical Manufacturers Association and Jaszczak phantom inserts are not optimised for SPECT reconstruction.

The talk focussed on the principles of fitting a function to time activity measurements. Taking the natural logarithm of the activity data and fitting a linear function introduces bias to the model from lower activities. Ideally, exponential functions should be approached with iterative methods to negate this bias. Jonathan covered the uncertainties of fitting parameters, including the often neglected covariance terms which may reduce the overall fit uncertainty. Single time point dosimetry was also introduced, where the apparent uncertainty is estimated from a patient sample. As Jonathan focussed on uncertainties for internal dosimetry, the main take-home was that the most complex calculation is not necessarily the best option. This is particularly true if the uncertainties in other steps of the calculation dominate. However, if a step is simplified, we need to be aware of the implications to the rest of the dosimetry chain.

Image reconstruction algorithms: practical considerations – Ian Armstrong

Is diagnostic nuclear medicine accurate?

Ian would argue that it is not, but this does not matter. If the data produced is precise and reproducible, and the results clinically meaningful, then this is all that is diagnostically required.

Ian's talk focussed on the controllable factors of reconstruction and their effects: resolution modelling, time of flight (TOF), and regularisation.

Resolution modelling improves spatial resolution and as a result increases SUV_{max}. If resolution modelling does not match reality then resolution losses are overcompensated for, resulting in Gibbs artefacts. However, this can be mitigated with an appropriate choice of parameters and post-filtering. Resolution modelling provides two improvements: a reduction in voxel variance, allowing for faster bed speeds and/or reduced administered activity; an increase in voxel correlation, meaning there is less concern with noise at smaller voxel sizes.

TOF increases signal-to-noise (SNR), which manifests as an improvement in sensitivity. Scan times and administered activity can be optimised with TOF. The theoretically achievable TOF gains are not attainable in reality due to reconstructing non-uniform activity distributions. Ian highlighted this as a reason why patient-specific optimisation should be performed rather than relying on theory, whilst using liver SNR as the ubiquitous image quality metric.

Regularisation (Q.Clear) incorporates a penalty factor that is dependent on the signal intensity relationship of a voxel and its near neighbours. A large difference between voxel values introduces a high penalty factor, and low differences a low penalty factor. Therefore, regularisation favours lower voxel-to-voxel signal changes which is then promoted through the iterative reconstruction. This leads to smoother, lower noise images, and increases SNR. For silicon photomultiplier systems, which inherently have improved noise characteristics over their traditional photomultiplier counterparts, less regularisation is required.

AI in reconstruction – Andrew Reader

There are two problems with conventional iterative reconstruction methods. Firstly, the Poisson log - likelihood term used to assess reconstruction convergence is minimised to agree with noisy data. This therefore creates a noisy image. Secondly, although this noise can be mitigated with regularisation, the regularisation hyperparameter and penalty function is difficult to determine rigorously.

Machine learning turns conventional iterative reconstruction on its head as it utilises knowledge of the ground truth during the reconstruction. Algorithms are trained by performing high-dimensional regression between the ground truth (image) and measured data (sinogram). Given a novel acquired sinogram of an unknown activity distribution, the algorithm can infer the resulting image according to a learned regression.

Although direct AI based PET reconstruction is fast, the main set-back is the huge training requirement. Typically, trillions of parameters must be optimised by the algorithm for 3D images. Therefore, these techniques are often generalised or limited to 2D reconstructions. A solution is to use CNNs which reduce the number of parameters, and allow the underlying physics and statistics to be incorporated into the reconstruction.

An example of a physics-informed reconstruction method was presented using an unrolled iterative method. Deep learning is included by enabling a CNN to optimally de-noise the image as a prior in a sequence of iterative reconstruction updates. In this example, the data-based iterative update needs to agree with the CNN de-noised version of the previous iterate.

Andrew proposed that to integrate machine learning into the clinic the models must start with simple and harmless tasks. Optimising the regularisation hyperparameter is one such example. In addition, any output should be given with an associated uncertainty estimate.

FURTHER INFORMATION

If you have suggestions for future IPEM events in nuclear medicine or other disciplines, please send them to **conferences@ipem.ac.uk** A recording of the above event is available on the IPEM website, visible to all registered delegates. For information on upcoming IPEM events, visit **ipem.ac.uk/what-s-on**

BOOK PITCH

Photoplethysmography: technology, signal analysis, and applications

Professor Panicos A Kyriacou and **Professor John Allen** outline the ideas behind and the content within their new book.

Throughout human history, light has played an important role in medicine. New optical technologies are revolutionising many fields related to applications in healthcare and wellbeing.

One optical monitoring technique of note is photoplethysmography (PPG). It is simple, low-cost and non-invasive and can detect pulsatile blood volume changes in vascular tissue with each heartbeat. PPG was discovered in the early 1930s and over the years has been established as one of the core optical technologies in healthcare. There is now considerable global academic and industrial interest in PPG, which is utilised extensively in pulse oximeters, wearable sensors - including personal health monitors and watches, imaging systems, as well as bespoke research devices for cardiovascular assessment. Recent advancements in signal processing technology, including machine learning and AI, have also opened new and exciting opportunities in PPG-based diagnostics.

Our unique book represents a first holistic state-of-the-art collection of articles on PPG. We bring together the essential topics with many contributions from leading authors in the field to cover the underlying principles of PPG, the technology (including wearable sensors and devices), advanced signal analysis techniques, a whole host of clinical applications, cutting edge research and applications, and future directions. The book also intends to provide a key reference source for biomedical engineers and medical physicists who need to become acquainted with new fields and topics. The content is also accessible to academics and students, entrepreneurs and innovators, and to medical professionals including clinicians working in a hospital and healthcare environments.

The book has 14 chapters and starts with a general introductory chapter with a historical perspective, followed by an inspiring discussion on the origin of the PPG in chapter 2. Chapters 3 and 4 cover PPG technology and wide-ranging PPG analysis including machine learning, AI and data synthesis, respectively. There are seven applications chapters; PPG in oxygenation measurement (chapter 5), two key vascular chapters considering the detection of peripheral arterial disease and assessment of the microcirculation (chapter 6), and assessment of arterial stiffness and endothelial function (chapter 7). Chapter 8 takes on the vogue area of low-frequency variability and autonomic function in PPG. Chapter 9 delves deeper into further enlightening physical and physiological interpretations of the PPG signal. Chapter 10 covers clinical monitoring utilising the PPG. The non-invasive cuffless measurement of blood pressure and wearable PPG sensors are detailed in chapters 11 and 12, respectively. Much so far has considered contact PPG technologies but chapter 13 considers imaging PPG and showcases a range of fascinating clinical applications. Chapter 14 presents some new trends in PPG research and highlights the bright future of PPG giving key future directions.

We hope the readership enjoy our endeavours and dedication to science and engineering in PPG. Who would have thought that just an LED and a photodiode in a sensor configuration could offer so much value in healthcare, giving exciting challenges to our future generations of researchers and innovators.

Imaging 1st

Imaging First Ltd, first opened in 2012 providing new and used ultrasound systems, probes, probe repairs and servicing options, we have continued to grow the business and are now on the NHSSC Framework for both equipment sales and servicing, with both new and used systems and probes in stock from a range of manufacturers.

Imaging First and Edan Medical

In 2019, we became the official UK distributors for Edan Medical ultrasound systems.

The Acclarix range starting with the AX3, with dual probe port and dual battery functionality, customisable touch screen interface in a 4.5kg lightweight body, produces great performance in a portable system, alongside its more powerful sibling, the AX8 with the addition of a tilt and swivel monitor and high clarity image quality, Edan have produced two portable systems that provide exceptional quality.

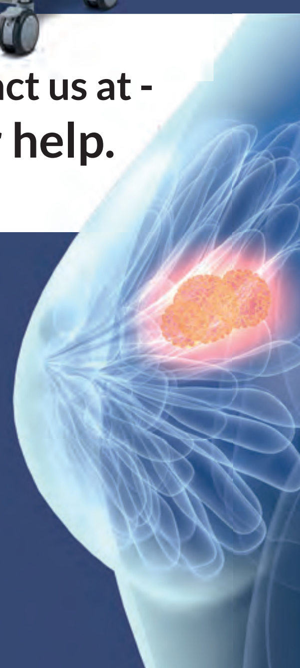
The new LX9 cart-based system, goes a step further in simplifying the experience for the user, it makes day-to-day operation an easy, fast and intuitive experience. With five probe ports, a customisable touch screen user panel and is available with additional options such as eLV, eOB, eVol.Flow and eFollical providing additional automated tools for stronger capabilities.

Imaging First and iCAD

In July this year, Imaging First became the official UK distributors for iCAD of their ProFound AI range of artificial intelligence for early breast cancer detection and diagnosis here in the UK. ProFound AI offers a solution that empowers radiologists to find breast cancer earlier and includes solutions for 2D mammography and tomosynthesis, ProFound AI also offers multi-vendor compatibility.

With two new options, ProFound AI Risk: The only clinical decision support tool that provides an accurate two-year breast cancer risk estimation that is personalised for each woman, based only on a screening mammogram and the age of the patient, and PowerLook Density Assessment: An automated solution to standardise the assessment of breast density to identify patients at higher risk of developing breast cancer.

All systems from Edan and iCAD are available to demo, please contact us at - info@imagingfirst.co.uk or on 0300 303 3600 for further help.



Precise. Powerful. Proven.

Discover the ProFound impact of artificial intelligence for digital breast tomosynthesis.

iCAD Imaging 1st

IF UNDELIVERED PLEASE
RETURN TO:-
IPEM
Fairmount House
230 Tadcaster Road
York
YO24 1ES
UK

CITIPOST MAIL Smart mail management

Delivered by Royal Mail C9 10020