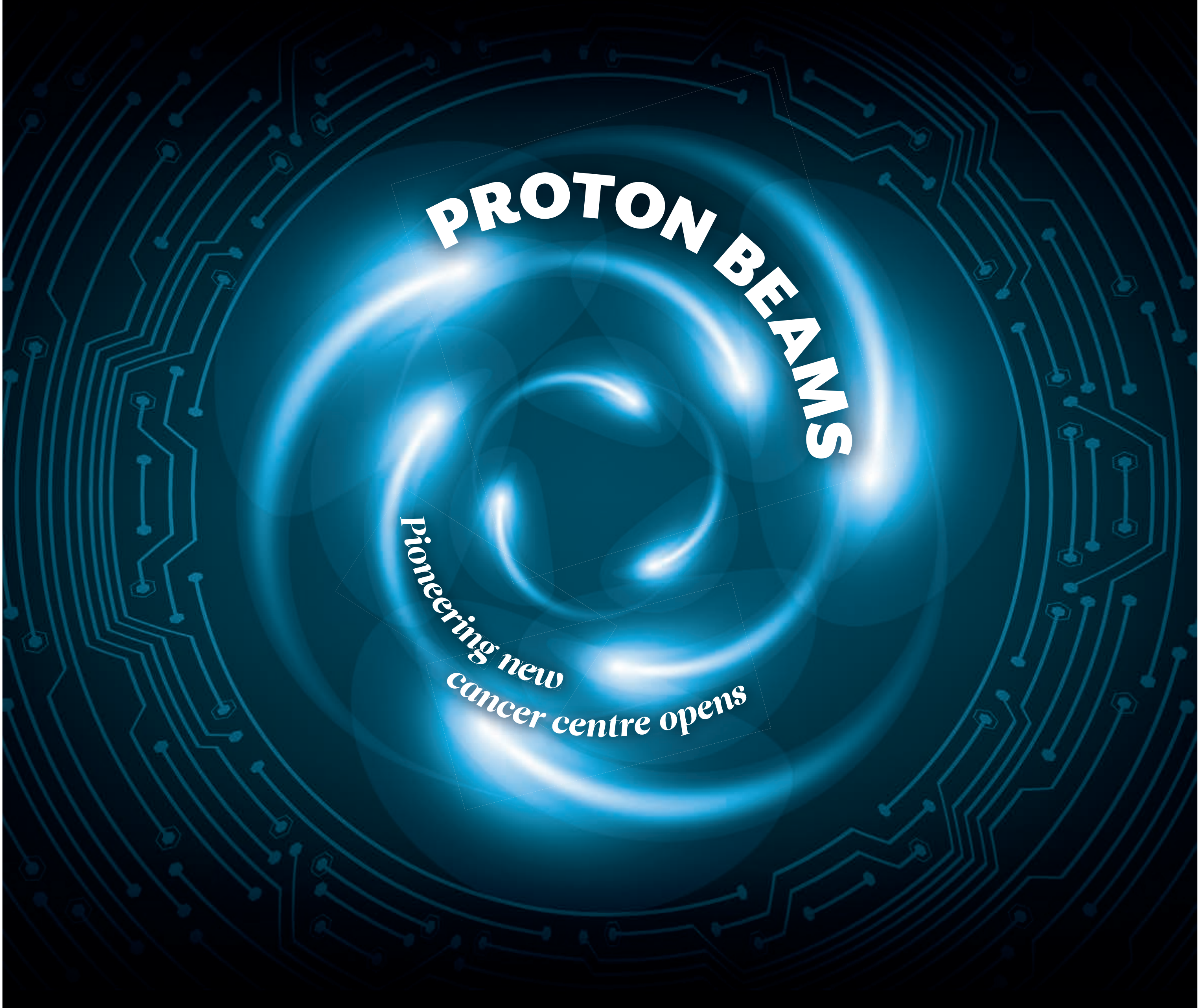
Volume 32 | Issue 1 | Spring 2022

IPEM
Institute of Physics and Engineering in Medicine

SCOPE



PROTON BEAMS

Pioneering new cancer centre opens

NEWS

Novel therapy that uses magnetic seeds to destroy tumours

HISTORY

The life story of the French physicist Paul Langevin

RADIOTHERAPY

Issues that can arise when refurbishing linac bunkers

IMAGING

The impact that COVID-19 vaccinations can have on scans

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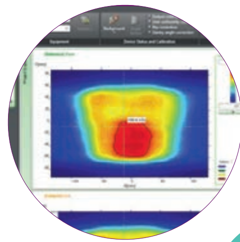

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Access all areas

Usman Lula outlines the content in the latest issue of *Scope*, including a behind-the-scenes look at a new proton beam therapy centre.

Welcome all to the first *Scope* magazine issue of 2022! With the latest developments on the horizon of the government dropping all COVID-related restrictions, we will soon find ourselves in another "new normal" period – where we ought to learn to live with viruses (however long that takes) and perhaps protect ourselves with boosters like seasonal flu jabs.

We've got some really exiting content in this issue – although we had a difficult job in trying to obtain as many promised features as possible during the Omicron wave.

You may remember that we had a special "proton therapy service" theme in the March 2018 issue of *Scope* (Volume 27, Issue 1). This was the year when the Christie NHS was getting ready to start introducing the service alongside other private entities – such as Rutherford Cancer Centres. Recently, another NHS centre started operating a proton therapy service – University College Hospitals in London. We thought we would interview Andy Poynter, Proton Physics Group Leader and IPEM Fellow, to give us an "access-all-areas" look at the developments, his take on the service as well as what the future holds. Interested? Flick to page 14 for more.

Andy Poynter gives us an "access-all-areas" look at the developments, his take on the service as well as what the future holds

There are lots of other really interesting features to get your teeth into, so what are you waiting for?

If you would like to contribute to *Scope* magazine in any way, please get in touch with me by emailing usman.lula@uhb.nhs.uk. We can discuss your proposal, agree on the contents, word limits and submission deadline. It's as easy as that and, what's more, it also acts as part of CPD.

A belated happy new year to all.

Usman Lula

Usman Lula
Chair of IPEM *Scope* EAB

INTERCONNECTING

Historical perspectives

"Retired" Professor David Thwaites, with all the work he still does (projects, supervising PhD students and more), requested, late last year, to include some historic snippets in *Scope*. Any knowledge from our retired colleagues is like gold dust – we really want them to share it all with us. So, here we are in the first quarter of 2022 with just that, well, a little longer than a snippet! You've already had a taster if you have been following David's exchange on the UK Medical Physics & Clinical Engineering academic discussion list (JISCMAIL). Here he provides a more comprehensive piece on Marie Curie, her roots, personal life and also achievements.

We do have another interconnecting historic piece, with Professor Francis Duck's subject of expertise, on Paul Langevin, the father of ultrasound. Francis talks about the discoveries of piezoelectricity and ultrasound, the war and the legacy left behind. A must read!

IPEM
Institute of Physics and Engineering in Medicine

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COVER FEATURE

Lead Physicist Andy Poynter gives a guided tour of a pioneering new cancer centre located 30m beneath the streets of London. He talks us through one of the UK's most advanced facilities for cancer treatment, which is now up and running and treating its first patients.

> It has been a massive job for us in terms of commissioning this facility under difficult conditions.
>
> – *Lead Physicist Andy Poynter* **page 14**

UPFRONT

Cover image by
SHUTTERSTOCK

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UPFRONT

MAGNETIC RESONANCE IMAGING

Magnetic seeds to heat and kill cancer

Scientists at UCL have developed a novel cancer therapy that uses an MRI scanner to guide a magnetic seed through the brain to heat and destroy tumours.

The therapy, demonstrated in mice, is called "minimally invasive image-guided ablation" (MINIMA) and comprises a ferromagnetic thermoseed navigated to a tumour using magnetic propulsion gradients generated by an MRI scanner, before being remotely heated to kill nearby cancer cells.

Researchers say the findings establish proof-of-concept for precise and effective treatment of hard-to-reach glioblastoma, along with other cancers such as prostate, that could benefit from less invasive therapies.

Senior author, Professor Mark Lythgoe from UCL's Centre for Advanced Biomedical Imaging, said: "MINIMA is a new MRI-guided therapy that has the potential to avoid traditional side effects by precisely treating the tumour without harming healthy tissues. Because the heating seed is magnetic, the magnetic fields in the MRI scanner can be used to remotely steer the seed through tissue to the tumour. Once at the tumour, the seed can then be heated, destroying the cancer cells, while causing limited damage to surrounding healthy tissues."

> MINIMA is a new MRI-guided therapy that has the potential to avoid traditional side effects

In the study, the UCL team demonstrate the three key components of MINIMA to a high level of accuracy: precise seed imaging; navigation through brain tissue using a tailored MRI system, tracked to within 0.3 mm accuracy; and eradicating the tumour by heating it in a mouse model.

The thermoseeds are spherical in shape, 2 mm in size and are made of a metal alloy. They are implanted superficially into tissue before being navigated.

Co-author Dr Lewis Thorne, a consultant neurosurgeon, said: "I treat patients with the most common form of brain cancer, glioblastoma. Following surgery, the average survival time is 12-18 months. MINIMA can successfully destroy cancer in a mouse and has the potential to extend survival and limit damage to adjacent brain tissues in patients."

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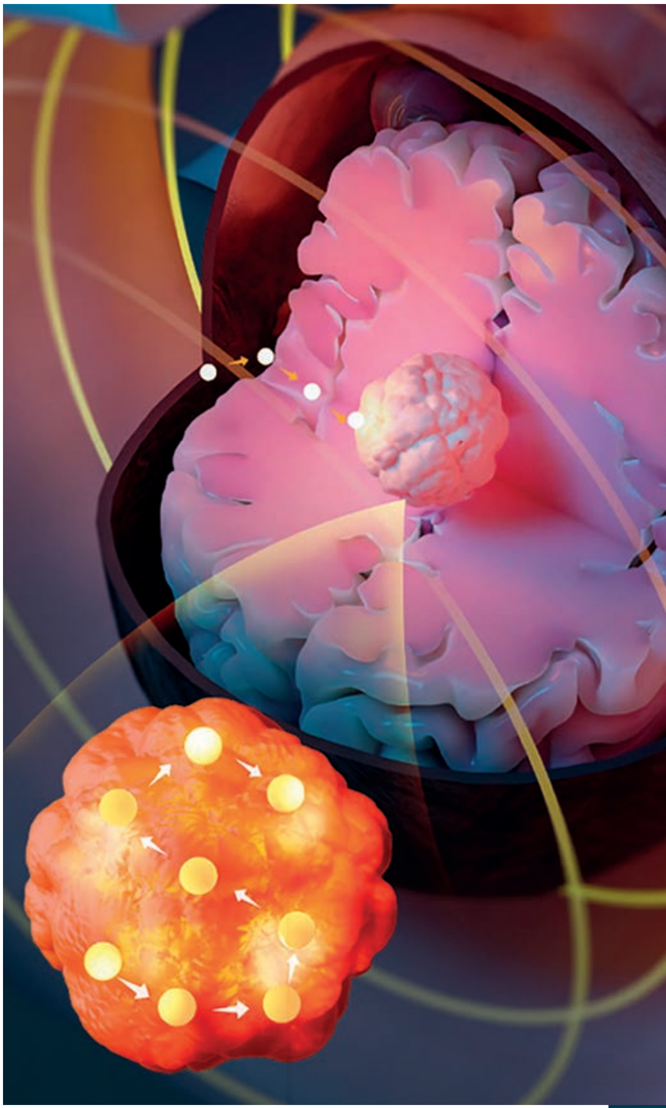

IMAGE: ISTOCK

FAST FACTS

2 mm
The ferromagnetic thermoseeds are 2 mm in size

0.3 mm
They can be tracked to within 0.3 mm accuracy

12-18 MONTHS
average survival time following surgery for glioblastoma.

ARTIFICIAL INTELLIGENCE

Robot performs laparoscopic surgery

A robot has performed laparoscopic surgery on the soft tissue of a pig without the guiding hand of a human – a significant step in robotics toward fully automated surgery.

The Smart Tissue Autonomous Robot (STAR) was designed by a team of Johns Hopkins University researchers.

Senior author Axel Krieger said: "Our findings show that we can automate one of the most intricate and delicate tasks in surgery – the reconnection of two ends of an intestine.

"The STAR performed the procedure in four animals and it produced significantly better results than humans performing the same procedure."

The robot excelled at intestinal anastomosis – a procedure that requires a high level of repetitive motion and precision.

Connecting two ends of an intestine is arguably the most challenging step in gastrointestinal surgery, requiring a surgeon to suture with high accuracy and consistency. The slightest hand tremor or misplaced stitch can result in a leak that could have catastrophic complications for the patient.

The robot is a vision-guided system designed specifically to suture soft tissue. The current iteration advances a 2016 model that repaired a pig's intestines accurately, but required a large incision to access the intestine and more guidance from humans.

bit.ly/3H8iBmY

INFECTION CONTROL

VIDEO ENGAGEMENT FOR HAND WASHING

Findings from a new study suggest that automated smart technology could help improve hand-hygiene practices to reduce the spread of healthcare-associated infections.

The researchers assessed whether an automated, smart video engagement system could increase the number of individuals who meet the recommended 20-second hand-washing duration.

The team developed a system comprising smart, connected, hand-soap and towel dispensers synched to a computer that was programmed to display a rotating set of 20-second-long creative videos.

Findings suggest that the video intervention significantly increased mean hand-washing duration and the number of users who achieved the recommended 20 seconds of hand washing, as compared to the control.

The team found hand washing time increased by up to 7.5 seconds.

bit.ly/3AV7AmE

NEWS IN BRIEF

Remote blood pressure monitoring

Using telehealth to monitor blood pressure at home for several months after a stroke had a positive impact on patient engagement and blood pressure control among people in historically under-resourced communities, according to new research. The work was presented at the American Stroke Association's International Stroke Conference 2022.

bit.ly/3glfbkZ

Personalised immunotherapy

An experimental form of immunotherapy that uses an individual's own tumour-fighting immune cells could potentially be used to treat people with metastatic breast cancer, according to results from an ongoing clinical trial led by researchers at the National Cancer Institute. In the clinical trial of 42 women with metastatic breast cancer, 28 (67%) generated an immune reaction against their cancer. The approach was used to treat six women, half of whom experienced measurable tumour shrinkage.

bit.ly/3rpa0a8

Preprint accuracy

A new study led by Dr Jonathon Coates of Queen Mary University of London, manually compared over 180 preprints to their published versions at the start of the COVID-19 pandemic. Coates said: "Approximately 40% of the early COVID-19 research was first shared as a preprint and these were used in policy and public health decisions." Coates and colleagues compared all the preprints from the first four months of the pandemic and found that over 83% of COVID- and 93% of non-COVID-related life sciences articles did not change from their preprint to final published versions.

bit.ly/3onM1WH

EXPERIMENTAL STUDY

Nano-sensors to pinpoint infectious diseases

A new paper describe a method for detecting viruses, such as Ebola virus and SARS CoV-2.

The technique, known as Nano2RED, is a twist on conventional high-accuracy tests relying on complex testing protocols and expensive readout systems.

The in-solution nano-sensors ("Nano2") serve to detect disease antigens in a sample by simple mixing.

The Rapid and Electronic Readout process ("RED") delivers test results, which are detectable as a colour change in the sample solution, and record the data through inexpensive semiconductor elements, such as LEDs.

The team, led by scientists at Arizona State University, say the technology represents a significant advance in the fight against infectious diseases.

It can be produced at a very low cost and compared with high-accuracy lab tests, such as ELISA (enzyme-linked immunosorbent assay), it does not require surface incubation or washing, dye labelling, or amplification. However, the authors say it still provides about 10 times better sensitivity than ELISA.

The approach is based on modular designs and could be used to test for any pathogen.

bit.ly/3Li9q5Y

UP CLOSE

MASK HACKS

WHAT ARE "MASK HACKS"?

Shortcuts and novel ways to increase the effectiveness of face masks.

TELL ME MORE

Researchers from the University of Cambridge tested seven different hacks to improve the fit of surgical and KN95 masks (similar to FFP2 masks in the UK).

WHAT WERE THE HACKS?

Sealing the edges with cloth tape, stuffing the gaps with first aid gauze, binding the mask to the face with gauze like a mummy, pressing the mask to the face with tights, knotting the ear loops, and using rubber bands to create a "brace".

WHICH HACKS WORKED BEST?

Two hacks – first aid tape and nylon tights – significantly improved mask fit. However the tights, in particular, were highly uncomfortable.

WHAT ABOUT THE OTHER FIVE HACKS?

The other hacks mostly improved the fit, but not by a significant amount.

HOW DID THEY TEST THE HACK?

They conducted qualitative and quantitative fit testing, with and without "hacks", on four participants. Qualitative testing is usually measured by spraying a flavoured compound and testing whether the wearer can taste the compound while wearing the mask. Quantitative testing measures the concentrations of particles both inside and outside the mask.

WHERE CAN I READ MORE?

Visit **bit.ly/3shr6pB**

COVID-19

NOVEL NANOPARTICLE SARS-COV-2 VACCINE

Scientists at The Wistar Institute have developed a COVID vaccine that, in animal studies, shows strong, broad, and durable protection in a single low dose.

The vaccine combines immune focusing, self-assembling nanoparticles and DNA delivery into one platform for the first time. It can also be stored at room temperature, making it potentially easier to transport to remote or developing locations.

Daniel Kulp from the Vaccine and Immunotherapy Centre at The Wistar Institute said: "This is among the first next-generation vaccines that will have more advanced features and broader protection."

The vaccine includes a rationally engineered receptor-binding domain using computational and structure-based design methodologies.

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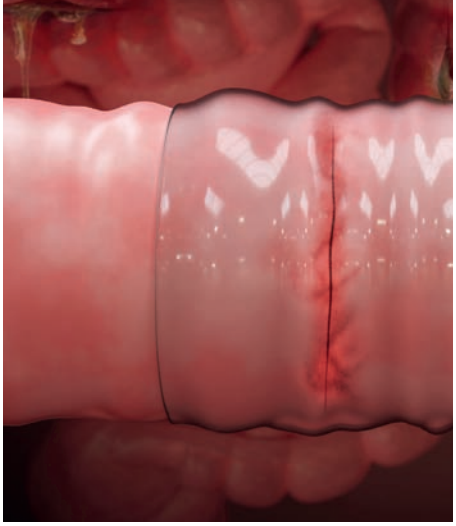

DATA ANALYSIS

MOBILE DEVICE DATA TO PREDICT COVID-19 OUTBREAKS

Researchers at the Yale School of Public Health were able to accurately predict outbreaks of COVID-19 in Connecticut using anonymous location information from mobile devices, according to a new study.

The novel analysis applied in the study could help health officials stem community outbreaks of COVID-19, the researchers said.

The key to the findings was the precision with which researchers were able to identify incidents of

high-frequency close personal contact down to the municipal level.

Forrest Crawford, Associate Professor of Biostatistics, said: "Close contact between people is the primary route for transmission of SARS-CoV-2.

"We measured close interpersonal contact within a six-foot radius everywhere in Connecticut using mobile device geolocation data over the course of an entire year.

"This effort gave Connecticut epidemiologists and policymakers insight to people's social distancing behaviour statewide."

bit.ly/3giRI9u

BIOENGINEERING

Surgical "duct tape" as an alternative to sutures

Engineers from the US have developed a kind of surgical duct tape – a strong, flexible, and biocompatible sticky patch that can be quickly applied to biological tissues and organs to help seal tears and wounds.

Like duct tape, the new patch is sticky on one side and smooth on the other.

The adhesive is targeted to seal defects in the gastrointestinal tract, which the engineers describe as the body's own biological ductwork.

In numerous experiments, the team has shown the patch can be quickly stuck to large tears and punctures in the colon, stomach, and intestines of various animal models. The adhesive binds strongly to tissues within several seconds and holds for over a month. It is also flexible and able to expand and contract with a functioning organ as it heals.

Once an injury is fully healed, the patch gradually degrades without causing inflammation or sticking to surrounding tissues.

The team envisions the surgical sticky patch could one day be stocked in operating rooms and used as a fast and safe alternative or reinforcement to hand-sewn sutures to repair leaks and tears in the gut and also other biological tissues.

bit.ly/3Gp72Xn

IMAGES: SCIENCEPHOTOLIBRARY / ISTOCK

INFECTIOUS DISEASES

QUICK COVID BREATHALYZER

A prototype "breathalyser" that can sensitively and accurately diagnose COVID-19, even in asymptomatic individuals, in less than five minutes has been developed.

The rapid antigen test is much quicker than reverse transcription-polymerase chain reaction (RT-PCR), but has a higher rate of false negatives and positives.

The researchers designed a handheld breathalyser that contains a chip with three surface-enhanced Raman scattering (SERS) sensors attached to silver nanocubes.

When a person exhales into the device for 10 seconds, compounds in their breath chemically interact with the sensors. Then, the researchers load the breathalyser into a portable Raman spectrometer that characterises the bound compounds based on changes to the molecular vibrations of the SERS sensors.

The team found that Raman spectra from COVID-positive and -negative

VIRAL RNA

More than 130,000 unknown viruses discovered

An international team has discovered more than 130,000 novel RNA (ribonucleic acid) viruses by using a new computer tool that analysed 5.7 million biological samples that have been collected around the world over the last 15 years. This finding, published in the journal *Nature*, represents a tenfold increase in the number of viral RNA species described to date.

To carry out this analysis, the multidisciplinary team developed Serratus, a cloud computing (Amazon Web Services, AWS) infrastructure that, using a cluster of 22,500 computer processors (CPUs), enabled massive searches for viral sequences in the millions of Gigabytes (Petabytes) of sequencing data available in public databases.

> This represents a tenfold increase in the number of viral RNA species described to date

Detailed analysis of certain viral families led to the discovery of more than 30 new coronavirus species, including interesting examples in aquatic vertebrates, such as fish and amphibians, whose coronaviruses had a genome segmented into two fragments – a feature that has been described in other virus families, but had not previously been detected in any coronavirus.

Both the database of all the viruses obtained in the course of this study and the set of tools developed are freely and openly available on the website serratus.io.

These tools can be of great use in characterising the diversity of all viruses existing in our planet and in preparing the world for possible new pandemics.

go.nature.com/3lXHIjy

people were different in regions responsive to ketones, alcohols and aldehydes, which they used to develop a statistical model for COVID diagnosis.

They tested the breathalyser on 501 people, who were shown by RT-PCR to be negative (85.2%), positive and symptomatic (8.6%), or positive and asymptomatic (6.2%) for the coronavirus. The method had a 3.8% false-negative and 0.1% false-positive rate.

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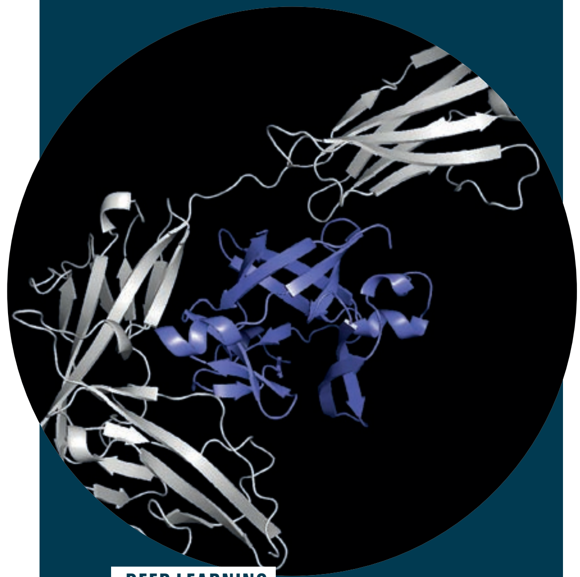


DEEP LEARNING

AI rapidly predicts how two proteins will attach

Researchers created a machine-learning model that can directly predict the complex that will form when two proteins bind together.

Their technique is between 80 and 500 times faster than state-of-the-art software methods, and often predicts protein structures that are closer to actual structures that have been observed experimentally.

This technique could help scientists better understand some biological processes that involve protein interactions, such as DNA replication and repair. It could also speed up the process of developing new medicines.

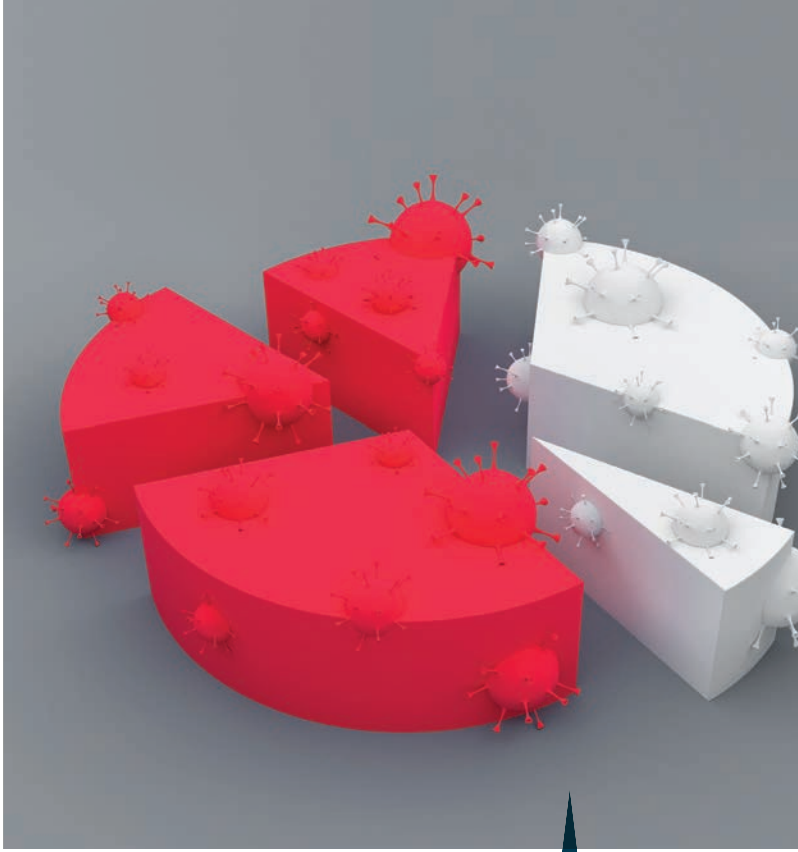
Octavian-Eugen Ganea, co-lead author of the paper, said: "Deep learning is very good at capturing interactions between different proteins that are otherwise difficult for chemists or biologists to write experimentally.

"Some of these interactions are very complicated, and people haven't found good ways to express them. This deep-learning model can learn these types of interactions from data."

bit.ly/3sg6Dl2

EXTERNAL RELATIONS MANAGER

A shocking picture



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

The new year began very much as the old one had ended, with concerns still being aired about how cancer services continue to be affected by the COVID-19 pandemic.

IPEM supported a snapshot workforce survey undertaken by Action Radiotherapy (which was renamed Radiotherapy UK in December). The survey painted a shocking picture of a sector trying to deliver life-saving services whilst being starved of investment.

The survey results showed services had been "hollowed out" and called for urgent action to properly fund radiotherapy and address workforce concerns.

The Daily Telegraph and the *Sunday Express* both covered the findings of the survey, which was also the subject of a special Catch Up With Cancer summit with parliamentarians in December.

Nicky Whilde, Chair of IPEM's Radiotherapy Professional Standards Panel, spoke at the summit, reiterating the points about the need for ring-fenced investment to replace ageing equipment and for action to be taken to address workforce shortages. You can read more about the survey on the IPEM website.

Away from matters concerning the impact of COVID-19 on cancer services, IPEM submitted a response to the Medicines and Healthcare products Regulatory Agency (MHRA) consultation on the future regulation of medical devices in the UK.

IPEM's Engineering Policy and Standards Panel led on producing an extremely detailed and comprehensive response to this, which a huge number of members contributed their views to, and

The survey results showed services had been "hollowed out" and called for urgent action

RADIOISOTOPE TECHNOLOGY

IPEM is exploring options to support the case to develop a small nuclear reactor to produce medical radioisotopes for the UK.

Many of the radioisotope-producing reactors across the world are due to be decommissioned in the next decade, with little in the way of replacements planned to come on-stream, potentially leading to a lack of availability of the material.

There is currently a proposal under consideration to build a new, small research reactor in North Wales, which needs to start construction within the next two years to help the UK avoid the worst of the potential shortages.

If no solution is found, the lack of radioisotopes will potentially affect the practice of nuclear medicine in its many forms and, therefore, patient outcomes.

A new Advanced Radioisotope Technology for Health Utility Reactor (ARTHUR) in North Wales would go a long way towards solving this problem and secure the UK's supply of medical radioisotopes.

IPEM believes this offers the UK an opportunity to secure the domestic production of a vital medical resource. IPEM has therefore joined with the Royal College of Radiologists and the Society and College of Radiographers to consider the project and is looking to meet with other relevant bodies to agree what steps might be taken to push the case with the UK government.

which was approved by both the Science, Research and Innovation Council and the Professional and Standards Council.

Staying with the MHRA, Dr Robert Farley, IPEM's President, was a joint signatory on a letter to the agency's board concerning the production of the Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use.

These guidelines have been produced by the MHRA since 1993 and are established throughout the UK as the foundation of MRI safety.

The letter, co-signed by the presidents of several other professional bodies, emphasised the need to keep the guidelines regularly updated in the face of potential plans by the agency to scale back its workforce. It stressed how critical the guidelines are to MRI safety for the protection of patients and staff.

Finally, efforts to explore how clinical technologists might become statutory registered professionals to help deliver better patient outcomes have moved forwards.

During the course of 2021, IPEM brought together a group of like-minded organisations to agree on the next steps to take with regards to this issue. A series of meetings were held towards the end of the year with a range of bodies and individuals to ascertain their views on the current situation and the likelihood of achieving statutory registration. Those meetings included with MPs from both sides of the House, PSA, HEE, officials from the Department of Health and Social Care, the Deputy Chief Scientific Officer for NHS England, and Scotland's Chief Professional Officer for Healthcare Scientists.

Further meetings are being held early in 2022, and a paper will then be produced for the coalition of organisations to agree on the way forward.

At the same time, at the start of the year the Department of Health and Social Care launched a consultation about when statutory registration is appropriate within the healthcare sector, which IPEM is responding to.

> **"THE LETTER EMPHASISED THE NEED TO KEEP THE GUIDELINES REGULARLY UPDATED IN THE FACE OF POTENTIAL PLANS TO SCALE BACK WORKFORCE**

IMAGE: ISTOCK

Lead Physicist and IPEM Fellow **Andy Poynter** gives a guided tour of a pioneering new cancer centre located 30m beneath the streets of London.

GOING

A new proton beam therapy centre

UNDERGROUND

Looking at the new University College Hospital (UCLH) Grafton Way building, just off Tottenham Court Road in central London, there is little to indicate that it contains one of the UK's most advanced facilities for cancer treatment. There's good reason for this, as the proton beam therapy centre is located almost 30 metres underground in an enormous basement complex that, given its cramped and teeming city location, presented numerous engineering challenges during its planning and construction.

The seed of this new centre was planted in 2008 with the launch of the NHS proton beam therapy programme, which began sending hundreds of patients for long and costly treatment at hospitals in Europe and the US.

In 2012 the government announced the allocation of £250m to develop two proton beam therapy centres in the UK, one at UCLH and the other in Manchester. The Manchester site, The Christie, opened in 2018. Its greenfield location offered fewer obstacles for the architects and engineers. The UCLH building finally opened late last year, having to contend with the added complication of the COVID pandemic, and has started to treat its first patients.

While proton beam therapy is not an especially new technology for treating cancer – the idea first emerged just after World War Two, treatment trials were held during the 1950s, and specialist hospital facilities began to appear during the 1980s and 1990s – the associated logistical and financial demands mean that dedicated centres remain relatively few and far between.

The major engineering hurdle for the UCLH building was fitting everything underneath an existing hospital. Further complications were the nearby London Underground tunnels, not to mention a lot of other very expensive adjacent property on which the development could have a lasting impact.

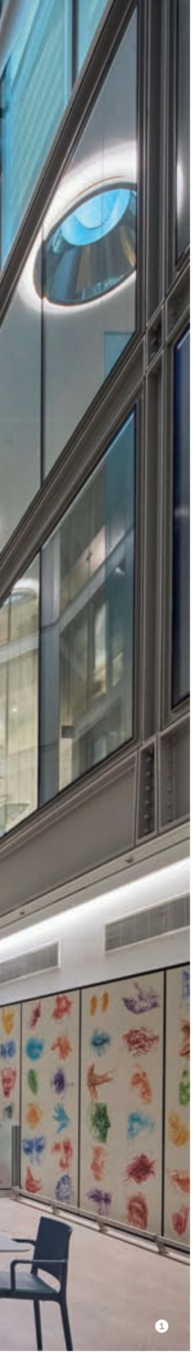
It was also a feat of planning and execution to deliver and install all the necessary technology, such as the cyclotron, weighing some 90 tonnes, which had to travel via lorry on a circuitous route avoiding the many London roads and bridges that have a limit of 50 tonnes or lower.

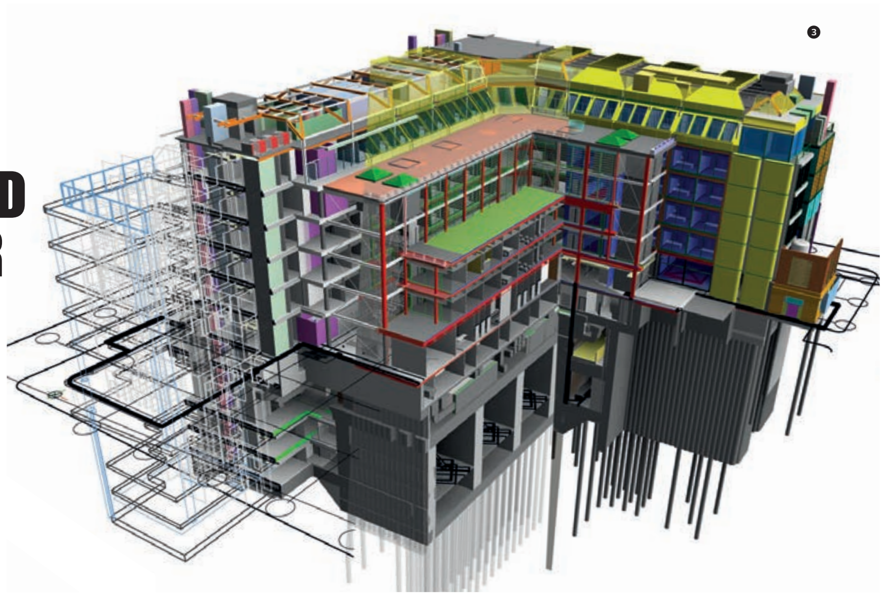
Bragg Peak

But what is it that proton beam therapy can do that justified all this effort that more conventional radiotherapy can't? The answer, says UCLH Lead Physicist Andy Poynter, rests in its more specialist application: "With radiotherapy, the X-rays are indirectly ionising as they pass through the patient, so the dose gradually attenuates as it goes through the body and out the other side. The way to get around that is by using multiple beams of X-rays, with a sort of crossfire that focuses on one place. So a high dose can be concentrated on a particular location and even on the shape of the tumour. But what can't be avoided is that exit dose, which means there is a low-dose bath of radiation given to a much larger area of the patient. It's unavoidable."

In many cases, the low-dose bath of radiation will not translate into that big of an issue. Conventional radiotherapy is a mature, accurate and effective therapy, and a life-saver for many people with cancer. But for certain cancers and certain patients, that low-dose bath can pose a significant problem – for them, an alternative approach is called for.

"Protons work differently and interact in a different way with body tissues," says Poynter. "They deliver a relatively low dose of radiation until they get to the





❶ The interior of the Grafton Way building.

❷ The exterior of the Grafton Way building.

❸ Cross section of the Grafton Way building, courtesy of Bouygues UK.

" A HIGH DOSE CAN BE CONCENTRATED ON A PARTICULAR LOCATION AND EVEN ON THE SHAPE OF THE TUMOUR

end of their range in the patient. And then they give off most of their energy over in those last few millimeters."

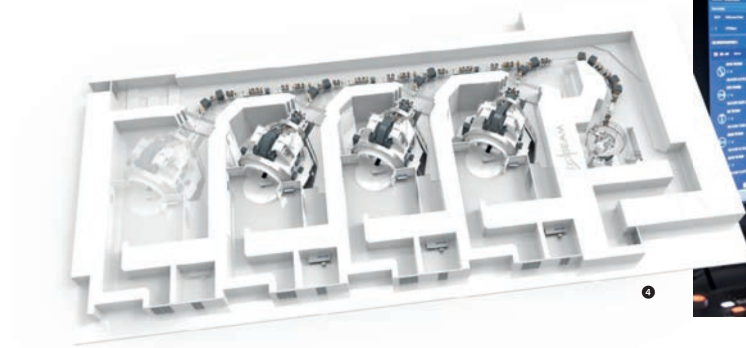
This sudden, dying burst of energy from the proton is the Bragg Peak. "Any talk on protons will always mention the Bragg Peak," says Poynter. "If you plot the course of protons on a line, you have a dose that remains fairly flat until you get a very sharp peak at the end of the range. Then the dose falls off to more or less to zero beyond that."

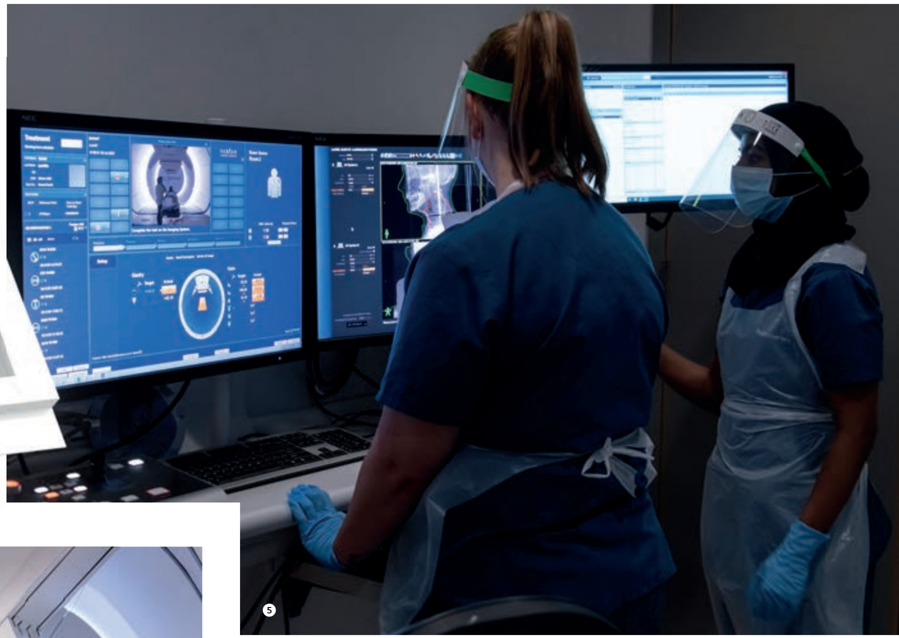
The key benefit of proton beam therapy is that the position of the Bragg Peak can be adjusted according to the energy of the protons. What this means in terms of treating the human body is that the Bragg Peak can be triggered to fire at just the right point, leaving no exit dose.

The proton-generating machine, a cyclotron, that sits in the basement at the UCLH building can fire the subatomic particles with an energy of anywhere from 70 to 245MeV (mega electron volts). "That spans a depth in the patient's body from about four centimetres down to nearly 40 centimetres," says Poynter. "However, each individual Bragg Peak is quite narrow, so if you need to treat a tumour at depth with protons, you have to stitch together several of those Bragg Peaks to broaden out the area that you are treating. A reasonable width of tumour can be covered by what we call a spread-out Bragg Peak. We also typically use two or three beams pointing from different directions. That way we end up with a dose that is shaped nicely to the area that we want to treat."

In effect, this more precise and targeted dose of protons greatly reduces the low-dose bath, so any body tissue around the tumour should remain untroubled by the radiation. The relative lack of threat to areas

IMAGE: ULCH, SCOTT TALLON WALKER





4 Illustration showing the gantries, courtesy of UCLH.

5 Radiotherapists in the control room, courtesy of UCLH.

6 Treatment room, courtesy of UCLH.

peripheral to the cancer can be especially vital for children. "Say we have an eight-year-old child and we need to treat a brain tumour on one side of their head. Traditional radiotherapy is not ideal, because the low-dose bath could lead to long-term side effects for that child, such as disturbances in the growth hormones, reduced IQ and so on.

"For that particular cohort, the advantages of proton beam therapy are clear and obvious. On the other hand, when treating an older adult the long-term effect of the low-dose bath might be less critical, in which case the advantage over conventional radiotherapy would be diminished."

Suitable conditions

As a result, the proton beam therapy centres in London and Manchester are mainly intended to treat patients with tumours of the brain and central nervous system. "We have a large cohort of paediatric and young adult patients with these cancers, sarcomas and similar diseases," says Poynter. "That said we also treat adults in situations where it's important that we spare them the low-dose bath of radiation – again, mostly with sarcomas, tumours at the base of skull, on the spine and so on."

Though there are few theoretical limits to the range of cancers that can be treated with proton beam therapy, for the time being the list of suitable conditions will remain narrowly defined because the treatment is so much more expensive than traditional radiotherapy. The benefits of treating any other cancer would have to be clearly demonstrated before the money would be allocated to widen the remit of the facilities.

"The running costs to provide this service runs into tens of millions of pounds a year," says Poynter, "so the cost per patient is quite high, which means we need to focus on cases where there is a clear and demonstrable benefit of using this technology.

"It could be pointed at lots of different tumours, but when we've already got a very effective and low toxicity treatment using conventional radiotherapy, why would you spend two or three times as much to use protons?"

Several different factors explain the elevated cost of proton beam therapy. The first is that the equipment itself is an order of magnitude more expensive than conventional radiotherapy.

On top of that, such a complicated and high-end piece of equipment calls for round-the-clock monitoring and maintenance, so requiring a permanent specialist on-site engineering team, which doesn't come cheap either. The day-to-day running of the proton beam therapy facility also demands a large multidisciplinary team, consisting of oncologists, radiographers and radiotherapy nurses, physicists and dosimetrists, an anaesthetic team, mould room technicians, health play specialists and a whole range of support workers.

"There is work under way to try to reduce the cost of proton radiotherapy, but you can't really get close to the cost of a conventional treatment at the moment. The future might bring cheaper types of accelerator, but that's a long way off yet," adds Poynter.

"IT HAS BEEN A LONG TIME COMING AND IT'S GREAT THAT WE'RE NOW OFF THE GROUND

The next few years

As the long list of personnel suggests, it is also a labour-intensive treatment. This is fairly usual when dealing with sick children and their parents, who all need more careful and concentrated help and support. To help smooth the experience, the facilities deep under the ground at Grafton Way include play rooms for children along with social and quiet spaces for adults.

The nature of the actual treatment also demands a more exhaustive approach than normal radiotherapy. Those exact, focused beams of protons allow little room for error, so the patient has to be very carefully positioned during each treatment session. Each beam of protons takes just a few seconds, but the patient may need precise re-adjusting between each of those doses. The time spent lying flat underneath one of the sleek treatment gantries in the deepest level of the basement can extend to more than half an hour. The typical course of treatments is 28 sessions, with each session on consecutive working days.

That's a long time for a child. For the really young, usually those aged seven and under, general anaesthetic is the best approach for each session. For those with tumours on the brain and at the base of the skull, custom thermoplastic shells are moulded to fit the child's head, keeping them perfectly aligned and motionless as the protons go about their intricate work.

While the work of the UCLH centre remains narrowly defined for now, trials are being developed that will look at expanding the list of indications for proton beam therapy. "We will be involved in quite a few of those over the next few years," says Poynter. "To give a couple of examples, there's a clinical trial running at the moment looking at its use in adult head and neck patients. The evidence still needs to be gathered to prove that there's a benefit in that particular group of patients.

"We're also collaborating on a trial for using it in breast cancer. There's a good theoretical advantage in using protons rather than radiotherapy in terms of sparing the heart, lungs and chest wall. But again, the real benefit hasn't been demonstrated yet in a clinical trial. But if both of those trials have a positive outcome, they would widen the scope of proton radiotherapy significantly."

For now, the team at Grafton Way is concentrating on ramping up the facility to its full capacity, which would involve all four gantries in operation, treating up to 650 NHS patients a year. The first patients were admitted in December, with just the two gantries being used. "It has been going very well," says Poynter. "It's complicated equipment and potentially poses more problems than conventional radiotherapy technology. But we've had very good uptime with the equipment so far, it's all gone very smoothly, and we've completed treatment for four patients without problem. We're planning to open the third gantry very soon and the fourth one later this year."

Given the complications of the immense construction project in the centre of London, beset by logistical issues and the small concurrent matter of a pandemic, the overriding feelings for everybody in the huge multidisciplinary team is relief and delight to be up and running. "It has been a long time coming and it's great that we're now off the ground with it."

Poynter is also keen to highlight the role of the physics team in getting the UCLH Grafton Way centre to this point. "It has been a massive job for us in terms of commissioning this facility under difficult conditions the past couple of years. Everybody has managed to keep going through all of it, doing a lot of the work remotely at one point, and then with heavy restrictions on how we worked after that. Now we're moving into the vital stage of supporting the clinical service and ensuring it runs smoothly. It has been a massive achievement."

PROTON BEAM FACTFILE

- The centre is the second of only two such NHS centres in the UK.
- The two centres will cover the whole of England.
- The national proton beam therapy service was funded by £250m of government investment.
- Ultimately, the centres will treat up to 1,300 patients from across England per year.
- Around a third of the patients will be children and teenagers.
- The treatment course takes around six weeks, with people staying in nearby accommodation and visiting the centre as outpatients each day.
- The cyclotron weighs 90 tonnes and is the size of a family car.
- It generates the protons spinning ionised hydrogen at two-thirds the speed of light.
- This beam is guided via massive magnets to one of the four treatment rooms, where a three-storey machine delivers the treatment to the patient with millimetre accuracy.

Andy Poynter *is Proton Physics Group Leader at University College London Hospitals NHS Foundation Trust and an IPEM Fellow. For more information, visit the website uclh.nhs.uk*

WHAT IS IN A NAME?

Marie Sklodowska-Curie and Polonium

David Thwaites considers naming in Marie Curie's life, from her Polish roots to her family's Nobel prizes (the first of an occasional series of historical fragments).

Marie Sklodowska-Curie is an iconic figure and there are many sources relating to her life and work. In looking at any history, equally so for science, it's often the serendipitous twists and turns that determine how events play out that are fascinating.

Marie (1867-1934) was born in Poland, as Maria Skłodowska (transliterated as Sklodowska/ Sklodovska), on 7 November – now the International Organization for Medical Physics's annual International Day of Medical Physics. Yet her working life was conducted in France and her partner was French, so she is often referred to simply as Marie Curie. Nevertheless she always retained a strong feeling for Poland, and often used the combined Sklodowska-Curie to emphasise that.

For three-quarters of her life, Poland as a country didn't exist. It had been partitioned between the Russian Empire, the Kingdom of Prussia and the Austrian Hapsburg Monarchy in the late 1700s and didn't regain full independent sovereignty until after WW1. Maria was born in Warsaw, the capital of the

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Polish province of the Russian Empire. Even the word Polish was removed in the year she was born (the province becoming Vistula Land), following uprisings against Russian rule. Strong Polish resistance groups continued to exist. Despite governing authority actions to suppress Polish identity, culture and education, among others, widespread movements worked to keep them alive. The Sklodowskas were significantly involved in this and were penalised financially for that. Her father, Władysław taught maths and physics and directed two boys' secondary schools, but was eventually forced out of those posts. Her mother, Bronisława, operated a girls' school, but stood down following Maria's birth and died when Maria was 10.

❶ Portrait Marie Curie.

❷ Marie Curie as a child with her brother and sisters. From left to right are Zosia, Hela, Manya (Marie Curie), Joseph and Bronya.

Maria to Marie

Maria and her siblings were not well off, meaning pursuing university study would be a struggle. Also, at the time, women weren't allowed to enrol at the University of Warsaw, which would have been her obvious first choice. Therefore she opted to go to France to the Sorbonne/University of Paris, where women could study. However, because of the costs, she agreed with an older sister (also Bronisława) to help fund the latter to study medicine at the Sorbonne first and then have her support Maria's studies later. Therefore she worked as a tutor and governess for several years, going to Paris in late 1891.

Until then she was known as Maria. Her younger daughter, Ève, in a biography of her mother (*Madame Curie*, published in 1938), refers to her formally using the archaic spelling, Marya. However, for most of Ève's account of Maria's time in Poland she uses Manya, her family's (i.e. Maria's parents' and siblings') diminutive name for her. When Maria arrived at the Sorbonne, she registered herself as Marie, (re-naming herself in the French style, possibly to better fit in) and this is how she was mainly known from then on outside her family and outside Poland. The change is reflected in Ève's use of Marie in the biography from that point on.

Marie received degrees in physics and maths in 1893 and 1894. She hoped to be able to return to a university post in Poland. However, again, this wasn't possible for a woman at that time. Hence she pursued her doctoral studies through Pierre Curie's lab in Paris and continued her scientific career thereafter in France. Marie had done some previous work in magnetism and met Pierre through that and from needing lab space! His doctoral thesis work was on magnetism, completed in 1895, whereupon he became a professor in the City of Paris School of Industrial Physics and Chemistry. He had worked previously with his brother, Jacques, demonstrating the piezoelectric effect in 1880 and the reverse effect in 1881, which would lead eventually to crystal oscillators (and to sonar and medical ultrasound). The brothers had devised and constructed sensitive piezoelectric electrometers capable of measuring small amounts of charge, which became instrumental in Marie's radioactivity studies. Marie and Pierre were married in July 1985, she becoming Mme Curie, but also often using the name Mme Sklodowska-Curie on publications and in other scientific contexts.

> "HENRI BEQUEREL DISCOVERED "THE RADIATING ACTIVITY" OF URANIUM SALTS IN EARLY 1896

Radioactivity

Henri Bequerel discovered "the radiating activity"of uranium salts in early 1896, whilst exploring possible links between phosphorescence and Röntgen's recently-discovered X-rays. Marie decided to investigate this phenomenon for her doctoral studies.

IMAGE: GETTY

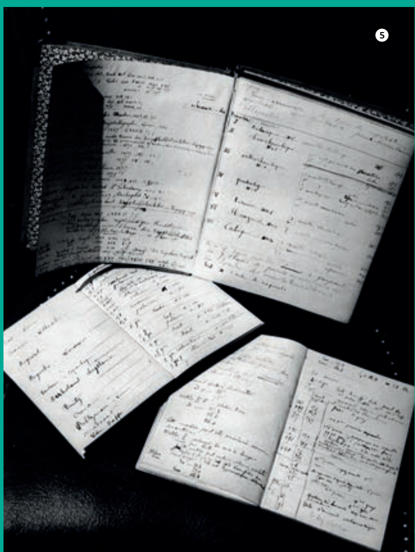
> "IN JULY 1898 THEY ANNOUNCED THEIR FIRST NEWLY DISCOVERED RADIOACTIVE ELEMENT

As part of that, she systematically tested the range of minerals in the collection of the School of Physics to identify others emitting similar ionizing rays, working initially in a damp basement. This eventually led to Pierre joining her in this exciting research area, which they named radioactivity. In July 1898 they announced their first newly discovered radioactive element: "If this new metal is confirmed, we propose to call it polonium from the name of the original country of one of us." In December 1898 they announced a second new element, with much stronger radioactivity, which they named radium.

From 1898-1902, they published more than 30 papers. One reported that the radiation from radium would damage and destroy tumour cells more effectively than healthy cells. In April 1902, after long and painstaking work in a rudimentary "miserable old shed", which had previously been a medical school dissecting room, they had finally isolated one tenth of a gram of pure radium chloride from more than a ton of pitchblende waste. Metallic radium was isolated in 1910. Between this and medical X-ray applications and developments, radiotherapy was born.

Pierre died in 1906, run over by a two-horse heavy cart in a street accident. In his memory, the Radium Institute (later the Curie Institute) was established in 1909 between the University of Paris and the Pasteur Institute. Its labs were completed just before WW1, so its work began properly only after the war. Marie directed one part, focussing on physics and chemistry research. The other, on the biological and medical effects and applications of radium and radioactivity, particularly for cancer, was directed by Claudius Regaud, a medic returning from war service.

Marie was later instrumental in establishing a second Radium/Curie Institute in Warsaw, officially opened in 1932, with her sister Bronisława as co-founder and first director. It is now called The Maria Sklodowska-Curie National Research Institute of Oncology.

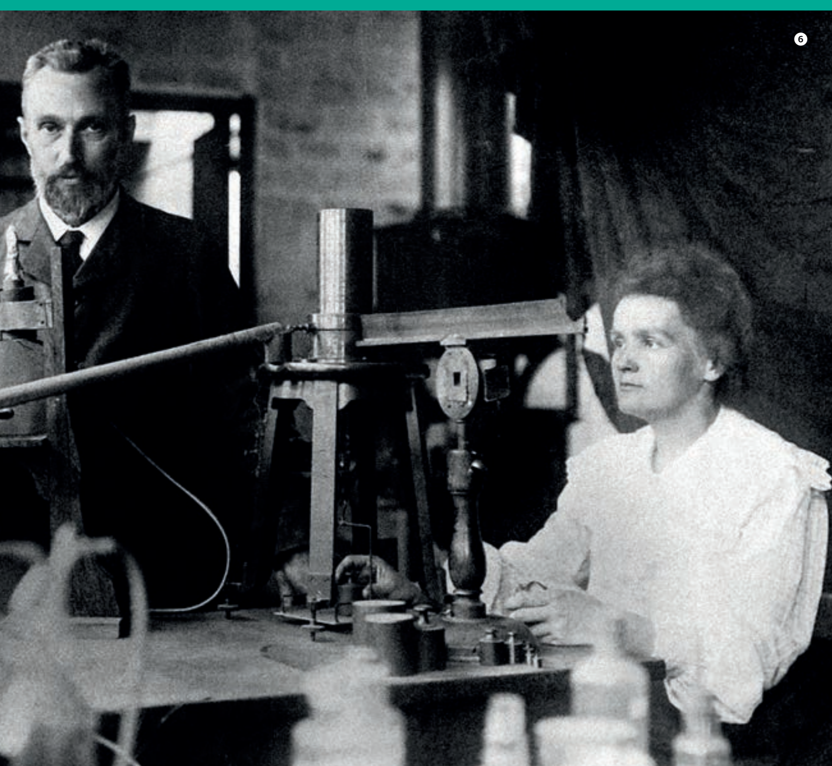


❸ Marie Curie

❹ The interior of Marie Curie's old laboratory in Paris.

❺ View of journals used by Pierre and Marie Curie.

❻ Marie Curie with her husband, Pierre Curie.



Polonium

Marie Curie strongly felt her Polish identity and ties throughout her life. She taught her daughters the Polish language, retained many links with her home country and was closely interested in its political position, the so-called "Polish question". The Curies' first-discovered new element was called polonium, in honour of her native Poland. This naming, when Poland was not in existence, was also a political statement to bring attention to Poland's plight and to highlight its partition and lack of independence.

It is said that Marie may have regretted calling the first-discovered element polonium and that this would have been better as a label for what became radium, since that was the recognised standard-bearer for radioactive materials with a much higher scientific and public profile.

Nobel prizes

Finally, of course, the Curie name resonates for Nobel prizes. It is well known that Marie Curie received two. The first was the 1903 Physics prize, which was split between Becquerel for his discovery of spontaneous radioactivity and jointly to Pierre and Marie for their combined work on radioactivity. This had been nominated to the Nobel committee by the French Academy of Sciences, but only for Bequerel and Pierre. Swedish mathematician and noted supporter of women in science, Magnus Goesta Mittag-Leffler, contacted Pierre to voice his concern. Pierre replied strongly that failing to acknowledge Marie was unacceptable. The research was her initiative. In the same year the Royal Society of London awarded the couple the Davy Medal, but the research had to be presented by Pierre, not Marie.

Marie's second Nobel prize was in 1911 for Chemistry, for the discovery of the elements radium and polonium, and the isolation and study of radium. In 1935, the Curies' older daughter and her husband, Irène and Frédéric Joliot-Curie were jointly awarded the Chemistry prize for their work on producing new artificial radioactive elements. Their younger daughter, Ève, became a journalist, war correspondent and member of the French women's medical corps. She married an American diplomat, Henry Labouisse, who later became Executive Director of UNICEF, with which Eve also worked. As an interesting footnote, Labouisse accepted the 1965 Nobel Peace Prize on behalf of UNICEF.

David Thwaites *is Professor of Medical Physics at the University of Sydney, Australia and an honorary Professor of Oncology Physics at the University of Leeds.* *He would like to thank Marius Grocki, Sheffield, for discussing the nuances of Polish language.*

PAUL LANGEVIN

The father of ultrasound

Francis Duck outlines the life story of the French physicist Paul Langevin in celebration of the 150th anniversary of his birth.

Paul Langevin was born in Paris on 23 January 1872. In 1946, the year that he died, the American physicist Walter Cady recognised him as "the originator of the modern science and art of ultrasonics". Langevin's discovery during the first half of 1917 of how to use quartz as an ultrasonic pulse-echo transducer, had created this new discipline in applied physics, and resulted in a plethora of applications in non-destructive testing, underwater acoustics, proximity sensing, chemical processing and, of course, medicine.

❶ Paul Langevin with Albert Einstein.

❷ Paul Langevin. Photograph by Henri Manuel.

Langevin and WWI

When the First World War broke out in Europe in August 1914, Langevin had only just moved back to his wife Jeanne and their four children. Three years earlier, Jeanne had started divorce proceedings against him, citing infidelity with Marie Curie, but the couple had settled out of court. Their son André later wrote that it was unsurprising that their "friendship, coupled with mutual admiration, should,

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several years after the death of Pierre Curie, be transformed little by little into love and an affair". Langevin's main priority was now to re-establish his shattered marriage. Moreover, as a pacifist, he wanted nothing to do with the war. Nevertheless, a short letter from Marie Curie ❺, written from Dunkirk on 22 January 1915, insisting that he "must urgently offer the services that only he can give", helped to change his mind. She was well aware of his brilliance. In her inaugural lecture in 1906, when she succeeded Pierre as professor of physics, she had spoken both of her own work in radioactivity and of Langevin's on gaseous ions. She recognised how he had built on her husband's work in magnetism to create an atomic theory of diamagnetism. She could not have anticipated that once again Pierre's work, this time on piezoelectricity, would form the basis for Langevin's solution to submarine detection.

It should be remembered how close Langevin was to Pierre Curie. His eulogy for his friend, following his tragic death on 19 April 1906, was heartfelt and sincere. He recognised the humanity of scientific discovery, and the way Pierre had worked intimately with his brother Jacques on the discovery of piezoelectricity and later with his wife Marie on radium and radioactive decay. Langevin speaks of Curie's understanding of the laws of crystal symmetries, mentioning the three binary axes in quartz and the electrical responses on compression in parallel and perpendicular to them.

Langevin spent the next two years working with the French Navy on a scheme to use ultrasound to locate U-boats. By February 1917, they had built working systems that generated beams of pulsed ultrasound at 100 kHz using mica transducers, and were working on a large area receiver using carbon granules. But these early technologies could never have formed the basis for the ultrasonic science that resulted from Langevin's next, brilliant innovation.

❸ A partially-cut quartz crystal.

❹ Attendees at the 1911 Solvay Congress on Physics. Langevin (far right).

❺ Langevin and Marie Curie in front of a group of women students in Paris, 1910.

❻ Advertisement for the S.C.A.M. ultrasonic sounder: 1928.

Piezoelectricity and ultrasound

There had been a flurry of interest in piezoelectricity after the Curie brothers' discoveries in the early 1880s, Wilhelm Röntgen being most notable for his experiments and Lord Kelvin and Helmuth Voigt for their theories. But by now piezoelectricity had been consigned to a minor topic in crystallography. It was only in Marie Curie's laboratory that the quartz piézo-électrique was still being used for measurements on radioactivity. It was Langevin who realised that, for a quartz crystal to act efficiently as a piezoelectric receiver of ultrasonic waves, it had to be cut along a different and very specific plane, one of three parallel with the main crystal axis. The plane of the cut was vital for success. Röntgen had shown elegantly that incorrect orientation could create a slice of quartz in which there was no piezoelectric response at all. So when Langevin described his new transducer as "a piece of stone, two sheets of tinfoil" he was being slightly disingenuous. It wasn't just any piece of stone but a very carefully cut section from the natural mineral quartz ❸. He soon showed that the same crystal cut, driven at a high frequency, generated a beam of ultrasound. Langevin's discovery was disseminated to the Allied laboratories in Britain and Italy, and in Washington since the US had just joined the war. By the end of the war, successful ultrasonic pulse-echo systems were being tested by both French and British navies.

> " LANGEVIN'S DISCOVERY WAS DISSEMINATED TO THE ALLIED LABORATORIES

All the immediate post-war work on ultrasound was derived directly from Langevin's breakthrough. The Canadian Robert Boyle had led the British asdics team and continued

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ultrasonic investigations back in Alberta. The American Robert Wood had visited Langevin and set up an ultrasound laboratory with Loomis at Tuxedo Park, New York: Frank Lloyd Hopwood, physicist at St Bartholomew's Hospital Medical School, had learned of Langevin's work through Boyle. Alexander Nicolson's development of the piezoelectric crystal Rochelle salt followed from the open communication with US industry.

Langevin published 20 papers and patents on ultrasonics and piezoelectricity during the period 1916 to 1935. After the war ended, he worked with Charles-Louis Florisson to develop a successful commercial system for depth sounding 6, sharing 10% of the receipts from patents with Marie Curie's daughters and Jacques Curie.

He delivered the first ever course on ultrasonics, at the Collége de France in 1923. With the visiting Japanese physicist Mishio Ishimoto, he developed a delightful device for measuring acoustic power. He foresaw its therapeutic use, but not its diagnostic use in medicine.

By this time, Langevin's reputation as a leading European physicist was established. He attended all the Solvay Congresses, starting with the first in 1911 4, becoming the Congress chair for those in 1931 and 1933. He was a close friend of Albert Einstein 1, independently developing Einstein's equation for the relationship between energy and matter, but using a different approach, and proposing him as a recipient of the Nobel Prize. He was a gifted teacher, and his lectures on relativity made this challenging topic more widely understood.

Politics and the Second World War

His student Pierre Biquard quoted Langevin as saying: "If we do not do our scientific work, someone else would, but if we neglect our political work, there would soon be no science." His international left-wing world-view emerged most visibly during the 1930s. In 1931 he was recruited by the League of Nations to join a four-man delegation to China to advise on the reorganisation of education there. Back in Europe, responding to the rise of fascism, Langevin founded the Comité de vigilance des intellectuels antifascists with his student, the physicist Frédéric Joliot. In 1939, he helped to found the Marxist quarterly *La Pensée*.

His pubic anti-fascist position made him a marked man under the German occupation. When the Gestapo arrested him, there was such a public outcry that, instead, he was placed under house arrest away from Paris, in Troyes. He was able to receive visitors, including Jeanne and their children, and was free to leave the apartment during the day, making occasional visits into the countryside. Most notably he continued his physics. His new work on neutron collisions was done at a time of deep secrecy surrounding the Manhattan bomb project. By contrast, Langevin published openly on the deceleration of high-energy neutrons.

His other work at this time returned to his youth and ion transport. It was published posthumously, by Eliane Montel. Although described as his secretary and friend, she was more than both of these. Eliane was a competent physicist, born in Montpellier in 1898. She had worked with Marie Curie, on Langevin's recommendation and subsequently spent a year in his laboratory. After the war, she implemented his proposed method to measure ionic mobility in gasses and in 1972 she took a leading role in the centenary celebrations of his birth. She was also more than a friend. Their son, Paul-Gilbert, born in 1933, sustained his father's association with acoustics by becoming a noted musicologist.

During his time in Troyes he learned that his daughter Hélène had been deported, and that her husband, Jacques Solomon, had been executed as a communist. Fernand Holweck, who had helped to develop ultrasound during WWI, was tortured to death by the Gestapo. By 1944 his friends were so fearful for his safety that they arranged his escape to Switzerland.

Legacy

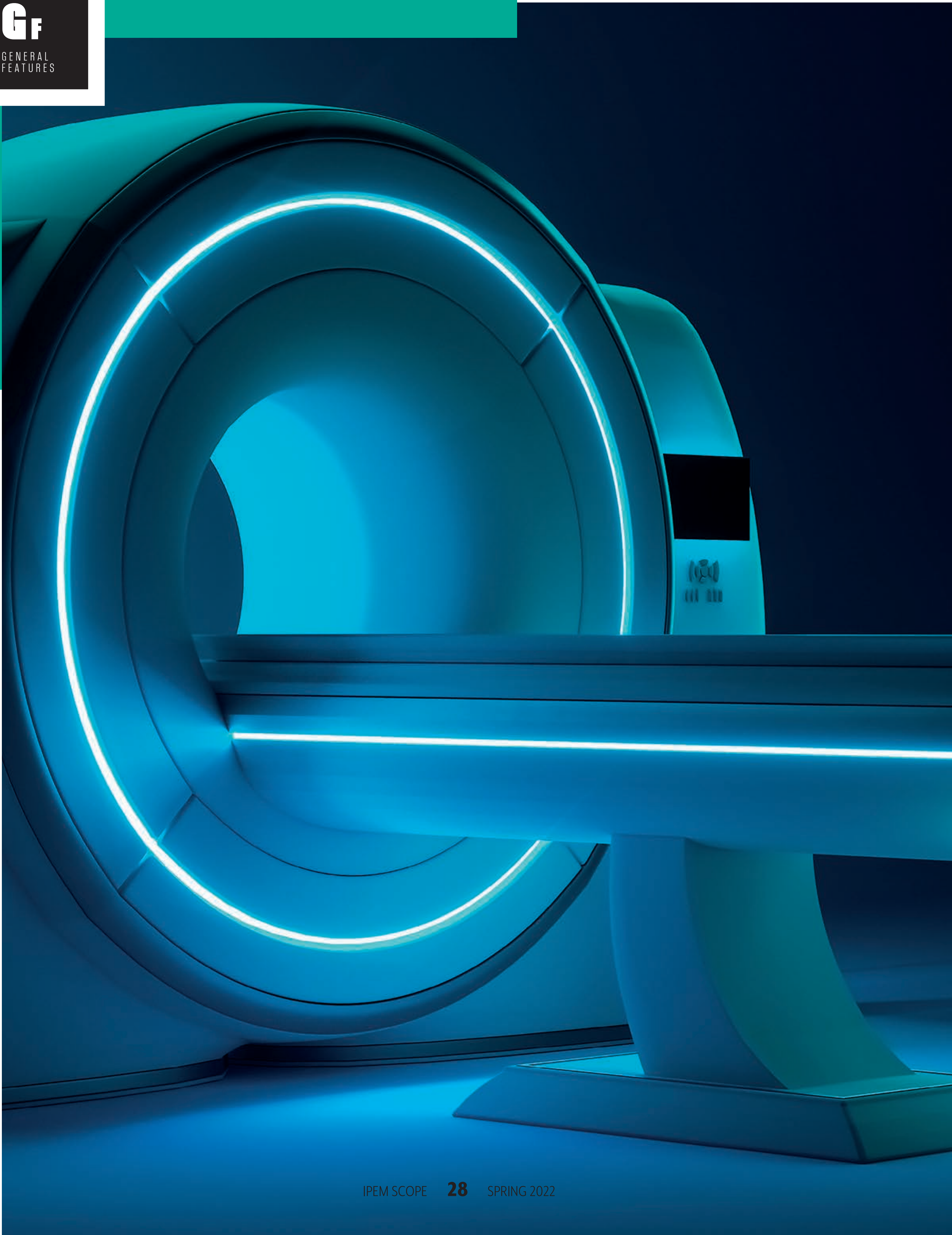
Langevin is honoured in France by his place in the Pantheon in Paris, alongside Marie and Pierre Curie. There have been three biographies in French, and one in Russian. But his memory has faded elsewhere. The British press belatedly noted his contribution to asdics. *The Times* obituary noted his recent public appointments in France: municipal councillor: chair of the Commission for Educational Reform: deputy chief delegate to UNESCO.

He remained a revered figure for French socialists but, very soon, the causes he espoused became terms of criticism, and his science became largely unremembered. On this 150th anniversary of his birth, it is time to recover his story.

FURTHER READING

Francis Duck is a retired medical physicist and IPEM Fellow who has spent most of his career working in medical ultrasound. Francis also wrote about Langevin's invention of the quartz piezoelectric ultrasonic pulse-echo transducer in a 2008 edition of *Scope*.

IMAGE: GETTY, ALAMAY



A PHANTOM STUDY IN THE PANDEMIC

Dr Bal Sanghera talks through his experiences of running a national PET-CT scanner phantom study during the COVID pandemic.

In the immortal words of Aesop:
There once was a speedy hare who bragged about how fast he could run.
Tired of hearing him boast, Slow and Steady, the tortoise, challenged him to a race. All the animals in the forest gathered to watch ...Slow and Steady won the race.

Wise words and a fitting metaphor during current times. Unless you are running a national Positron Emission Tomography – Computed Tomography (PET-CT) imaging project incorporating a phantom where time is the enemy due to radioactive decay.

A deep sigh of relief escaped after finishing my usual early-bird morning session PET-CT physics talk at the annual Royal Society of Medicine (RSM) PET-CT meeting a few years ago. The meeting has been organised for well over 20 years by my radiologist colleague Dr Wai Lup Wong who acts as National Specialty Advisor [PET-CT] NHS England.

We both work at the Paul Strickland Scanner Centre (PSSC), an independent charity based at the Mount Vernon Hospital site in northwest London, and jointly appreciate the synergy between physics and radiology both at a local and higher national level.

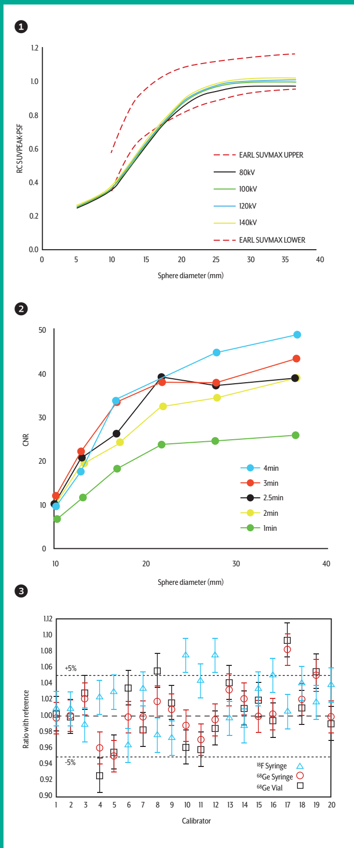
Regarding this, one of the RSM sessions involved a vehement discussion between clinicians about the challenges of using vendor-supplied advanced software algorithms to visualise and quantify cancer in PET-CT images. Vendors often supply proprietary advanced software, e.g. resolution recovery (RR) techniques, to assist clinicians in identifying and quantifying lesions.

Such software is needed to correct for degradation effects on the spatial resolution arising from physical factors with the added advantage when implemented of improved quantitation. However, such algorithms regularly come with a disclaimer stating vendor software should be investigated fully to understand their influence under local imaging conditions.

Further investigation

From the enthusiastic nature of the RSM discussion described above, it was clear the use of advanced RR software needed more investigation. Especially as there may be potential for significant impact on visual assessment and quantitative standardised uptake values (SUV) used in PET clinical disease reporting. Cases had emerged where inadvertent changes to RR software, e.g. by vendor engineers or clinicians, had subsequently changed the number of lesions reported. It is now more widely acknowledged there can be a steep learning curve in fully understanding the advantages and disadvantages of integrating new technology in a clinical setting. However, such challenges are routinely undertaken by your friendly neighborhood medical physicists who collaborate with clinical colleagues and can advise on such matters. On this point, had the genius Chinese military strategist and author of *The Art of War* Sun Tzu been aware I'm sure his quote would have read: "Keep your friends close; keep your enemies closer but keep your physicists closest."

NHS England must have been thinking the same thing. The opportunity to work at a higher level arose through the introduction of the newly established Chief Scientific Office Knowledge Transfer Partnership programme (CSO-KTP). It was a competitive scheme where candidates proposed significant projects with collaboration from national metrology institutes. In my case ,the National Physical Laboratory (NPL) in Teddington. I already knew staff at NPL having previously organised a joint IPEM-NPL open day there.



1 Scanner response to accepted RC limits (red dotted lines) to establish potential bias.

2 CNR for different scan times demonstrating less contrast as time per scan reduces.

3 Recent Ge-68 surrogate F-18 syringe PET dose calibrator comparison study showing good compliance nationally. The data are plotted for measurements in both a syringe holder on the calibrator dipper, and for a vial placed at the bottom of the dipper.

During the interview, following a project interrogation, the panel asked what I would take if I were stranded on a desert island? I replied: "My collection of imported 1960s American vintage comics." This, along with the rich concept of a NHS cost-neutral national study, must have impressed the panel, who awarded me one of the four inaugural associate positions. For general reference and Sun Tzu fans, three of four successful applicants were physicists.

In essence, the CSO-KTP post offered the ability to forge multicentre collaborations but, critically, without solid funding… strange there's always a sting in the tail. The position also came with much valued King's Fund leadership training, which helped with management skills and coordinating this study.

Aim

My CSO-KTP study proposal was to collaboratively design and obtain a single long-acting solid Ge-68 traceable radioactive phantom, then transport and scan this at different PET-CT scanning centres across England, thereby enabling a national comparison of scanner response under local clinical imaging protocols with and without advanced software algorithms (e.g. RR) using the same precisely defined traceable phantom. Besides looking at site variations this also promoted the opportunity to investigate national harmonisation and benchmarking initiatives in potential future approved routine clinical PET-CT scanning. This has special significance now PET-CT had become a specialised commissioned service across England.

Methodology

The National Electrical Manufacturers Association (NEMA) image quality phantom consists of a low-activity fillable plastic torso containing six fillable higher-activity spheres of different diameter and a separate lung insert. Different compartments are manually filled, typically with short-lived liquid radioactive F-18 solution at PET sites locally, but this process can introduce uncertainty. Attempts to fund a traceable longer-lived solid NEMA Ge-68 phantom with an extra smaller sphere through industry colleagues fell on deaf ears; probably due to poor charisma and communication skills on my part.

However, NPL very kindly helped design, purchase and transport the phantom to individual PET centres like the PSSC with my colleague Gerry Lowe who has supported this study at PSSC. Following helpful discussions, a prototype acquisition protocol was kindly supplied by Lucy Pike from the PET Core Lab at St Thomas' Hospital, which has a long history of national PET trial research QA. As part of this process, we made sure to contact each site and explain the study requirements in advance, so data acquisition complied with the protocol. Sites were asked to scan the phantom under clinical protocols using 120kV CT (to avoid potential bias with tube voltage) in list mode for PET with three acquisitions for harmonisation comparison if possible. Some PET-CT vendors operate scanners using step and shoot acquisition with a bed overlap to achieve uniform sensitivity while others operate with continuous bed motion acquisition.

List mode acquisition afforded the opportunity to later run post-processing reconstructions with and without advanced imaging algorithms for an estimate of their impact on local scanning under clinical conditions. Centres were asked to upload data to the NPL data repository for later analysis.

In this way we had a plan to see the variation in PET scanner

> WHAT COULD POSSIBLY GO WRONG? SURELY NOTHING COULD STAND IN OUR WAY

response to the same radioactive image quality source under clinical conditions with and without RR software across the country – valuable information for potential future harmonisation and benchmarking implementation of clinical PET-CT to maintain high standards nationally.

What could possibly go wrong? Surely nothing could stand in our way.

Until March 2020, of course, and a terrible pandemic bore down upon us all with devastating worldwide consequences and fatalities – COVID-19.

A new normal imposed itself globally. However, despite our multiple lockdowns, new working practices, staff shortages and clinical workflow priorities, among other measures, when appropriate we continued to send the phantom to various sites and slowly acquired data safely during the pandemic.

Aesop certainly knew a thing or two and was most definitely ahead of his time.

Initial results

Presented are some preliminary example results from one centre highlighting the versatility of the modified NEMA phantom. Here parameters investigated for each radioactive sphere are:

- **Recovery coefficient (RC) for each sphere.**

RC = measured signal / true signal. This metric defines upper and lower limits of acceptable scanner response to different sized spheres as defined by the PET Core Lab or European Association of Nuclear Medicine (EANM). Results are shown with different CT tube voltage to highlight possible bias ❶ . As well as SUVpeak, this was done with different SUVs i.e. SUVmax and SUVmean. RR software is included in these data. In the vast majority of cases the scanner response conforms to expected limits.

- **Contrast to noise ratio (CNR) for each sphere.**

CNR = measured signal – background / background standard deviation. This metric may be considered a useful guide to determine how difficult it is to identify an object from its surroundings. Results were acquired at 120kV to reduce potential bias and show the effect of reduced CNR with decreased scan time ❷.

Discussion

We are about to perform full data analysis now with NPL as the phantom has decayed much during the pandemic. It is important to ensure consistency in performing measurements to reduce uncertainty in results. Some preliminary analysis has revealed meaningful RC and CNR results ❶ and ❷, which is reassuring and confirms the project's potential to inform about national PET-CT routine clinical scanning.

We stress the project's aim is not to name and shame individual sites or vendors as we intend to anonymise individual centre results before wider dissemination and publication. It's more about showing evidence that we are all complying to some basic standard for our routine clinical work. Not all centres use the same protocols for research and standard of care.

Collaboration and communication have been key to getting this project to its current status, especially during the pandemic. Accordingly, it is recommended respective national clinical training schemes ensure all trainee/junior radiologists are made fully aware of potentially significant qualitative and quantitative changes to outcome possible when unintentionally manipulating advanced imaging software. To minimise problems, I do a short tutorial to new PET reporters here at the PSSC regarding impact of software on PET images.

Future aims

We have a higher goal in mind than just publishing this study – to help facilitate a future funded and agreed harmonisation / benchmarking system to maintain and improve routine clinical PET imaging services nationally. In support of this we performed a national Ge-68 surrogate for F-18 PET radioisotope dose calibrator study recently, published in September 2020 in Nuclear Medicine Communications, with promising results for radiation dose calibrator compliance ❸. This study and our ongoing CSO-KTP study lends credence to a proposed future scheme where a combination of long-lived Ge-68 syringe and Ge-68 NEMA traceable phantoms can be sent to individual PET centres (including PET-MRI) to evidence conformity to an accepted standard. This process can also be realised as a criterion in the Quality Standards for Imaging (QSI) framework for ensuring quality. Any future proposed standards must also be adaptable and embrace perpetual evolution of software and hardware technology in imaging. NPL and the PET Core Lab have already very kindly and significantly collaborated in this project and their expertise would be ideal in such a proposed quality system moving forward.

__Dr Bal Sanghera__ is Inaugural Chief Scientific Officer's Knowledge Transfer Partnership Associate at Paul Strickland Scanner Centre, Mount Vernon Hospital. This article is co-authored by Gerry Lowe, Physicist, Mount Vernon Hospital.
Dr Sanghera would like to thank everyone who has helped with this project, especially during such difficult times. Of particularly note he'd like to mention CSO-KTP, Kings Trust, Andy Fenwick, Lucy Pike, Professor Sally Barrington, Ian Armstrong, Peter Julyan and Claire Strickland.

GF
GENERAL FEATURES

LINAC BUNKER REFURBISHMENT

A cautionary tale

Colin Jennings outlines some of the potential issues that can arise when refurbishing existing radiotherapy linac bunkers.

The Rosemere Cancer Centre opened in 1996 as a satellite centre of the Christie Hospital, Manchester. We started with just two linac bunkers, a simulator and a superficial x-ray treatment unit (SXT). The two bunkers were quite small, with narrow mazes that a standard hospital bed could not fit down (rather short sighted, as we found out later). This meant that the linacs had to be delivered via a hole in the back wall of the treatment bunker.

Our centre now has eight linac bunkers, two CT scanners and the SXT unit. During the 26 years since we opened we have had 15 linac installs/replacements and seven bunker refurbishments. As radiotherapy has evolved these replacements have come with new treatment features e.g. increased maximum field size, increased energy and increased maximum dose rate [1].

One of the main challenges when we came to refurbish our oldest two bunkers (LA1 and LA2) was that we were no longer a satellite of Christie Hospital and the original plans for the rooms could not be found.

There was some uncertainty over what thickness the walls actually were, the length of the primary barrier shielding, the amount of protection in the roof void, if they were protected for 10MV or only 6MV etc. There was also confusion over the material used for the bunker construction,

IMAGE: SHUTTERSTOCK

"THERE WAS UNCERTAINTY OVER WHAT THICKNESS THE WALLS WERE

as several of our bunkers have some barriers constructed from Magnetite high-density concrete. Magnetite is concrete containing aggregate with a high iron content. This typically gives a density of 4000Kg/m3 compared to the standard value for concrete of 2350Kg/m3.

Just as a final complicating factor, the position of the isocentre has changed in some linac bunkers to increase space or allow for some specific radiotherapy techniques e.g. Total Body Irradiation (where a long source to patient distance is required).

The bunkers for LA3 and LA4 have evolved to incorporate Magnetite and a new isocentre position ❹. The advantages of this new design for rooms 3 and 4 are a wider maze so linac delivery is simpler and a larger treatment room for the same bunker footprint. The downside was that the primary barrier in LA2 now did not extend far enough for the new isocentre position and an extra set of shielding plates had to be added in LA2 ❷.

Our biggest challenge to date was the refurbishment of linac room LA2. As previously mentioned, the space is too narrow for a linac delivery down the maze and previous refurbishments have used an opening in the back wall of the bunker. However in recent years there has been building works and cabling added to the exterior wall which now prevents this. Our only option was to partly demolish the maze to be able to deliver the new linac directly into the linac bunker and then re-build the bunker back up again afterwards. This proposal added two weeks to the bunker refurbish and approximately £50,000!

❶ Comparison of an early linac (top) with latest model (bottom)

Not for the faint hearted

Before these extensive works were undertaken, a dose rate survey was carried out to get a feel for the dose rates with the old linac in place and to ascertain a "baseline" for comparison with dose rates post works. Consideration of slightly different energies, and significantly higher dose rates for the new linac would have to be taken onto account too.

The building works were to widen the maze entrance and demolish the maze wall, allowing delivery of the larger linac items. Once delivered, the linac would be suitably protected to allow the builders to return and rebuild the maze. Once completed the rest of the linac was delivered and install could begin.

The demolition works were not for the faint hearted to say the least, with a diamond tipped bandsaw cutting the thick concrete maze wall into large slabs. These large slabs were then broken up using a remote control jackhammer (over a period of five nights to reduce noise disturbance to patients and staff during the day) – ❸ gives some idea of the extent of these works.

Eventually, we were ready for the linac delivery, which proceeded without problems. The linac was safely wrapped up and the rebuild began. This involved using high-density brick and high-density mortar, with the brick joints staggered horizontally and vertically.

The next stage

Following the linac install, a final dose rate survey was carried out. The results were similar to those pre-refurbishment (for flattened beams) and obviously significantly higher for the high doserate flattening filter free (FFF) beams. However, all results were accepted by our Radiation Protection Advisor.

The next stage of the project was working with the equipment supplier on the critical exam and some significant issues were found that need to be shared. All of our linacs have an isolator key that is supposed to remove power to the linac. Unfortunately we found that the isolator key was wired incorrectly such that in the "off" position the linac was on and in the "on" position the linac was off! We also found that the beam exit timer did not need the confirm button to be pressed to close the door interlock.

The most troubling finding of the critical exam, however, was the inoperation of our Castell Key system. This system is used to control access to the roof void space above linacs LA1 and LA2. There is a door to the roof void, which requires three keys. Two of these keys are locked into the interlock chain on linacs 1 and 2. We removed the castell key from LA2 and found we could still run a beam.

This was potentially extremely serious as the linac roof is not shielded (as far as we know due to the absence of detailed plans) and, as such, there is a risk of a potentially fatal radiation dose without this interlock system.

A linac engineer attended following our findings. The isolator switch and door interlock were quick and easy fixes. However, following some investigations, it turns out that the castell key interlock is an item part in the linac software (external terminate).

Values in software default to an inactive state where the hard-wired Castell key has no effect. Even if the values are set correctly in the software they can be "masked out" in service mode. Once masked out the linac can be run as normal with no warnings that the vales are masked out.

One saving grace is that once set correctly the software values cannot be masked out in clinical mode and the interlock will operate. However, there is a significant risk when the linac is running in service mode to staff who may enter the roof void area. We raised this as a serious concern with the manufacturer and reported the matter to the MHRA. They conducted they own internal investigation and confirmed our findings. The install manuals did not require any setting up or testing of the external interlock systems (thereby the default setting of inactive will be present). The manufacturer is now looking at re-configuring the castell key system into the room door interlock circuit, which cannot be over ridden in software.

They are also in process of updating their install manuals to ensure that all external interlocks settings are tested as part of the install procedure.

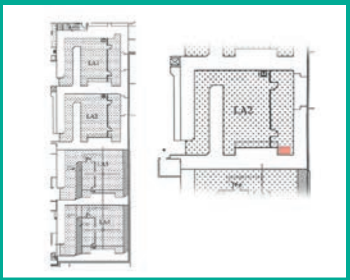
During the 26-year history of the Rosemere Cancer Centre, many issues have been encountered with linac refurbishments. I would like to finish with a word of caution to others that refurbishments are often far more difficult and complex than new builds due to insufficient information, changes in room access, movement of isocentre, changes in linac characteristics, changes to adjacent room occupancy and many other factors. As such, the decision to undertake refurbishments shouldn't be taken lightly.

__Colin Jennings__ is Deputy Head of Radiotherapy Physics at Rosemere Cancer Centre, Lancashire Teaching Hospitals. This article is a more detailed account of a presentation that was given at the RPA Update meeting in June 2021.

" REFURBISHMENTS ARE OFTEN FAR MORE DIFFICULT AND COMPLEX THAN NEW BUILDS

❷ extra shielding for the primary barrier, required in LA2.

❸ Maze demolition works



❹ Shift in isocentre position and Magnetite walls

FINDING THE FAULT

Utilising free and open-source software

Radiotherapy Engineers **Nino Manikandan** and **Priesh Mistry** look at tracking and resolving faults using self-hosted web applications.

IMAGE: SHUTTERSTOCK

This article aims to analyse the potential of utilising free and open-source software (FOSS) to track the progress of radiotherapy machine fault resolution within the NHS, as well as maintaining an accurate database of machine faults. In this particular instance, the focus will be on a piece of open-source software called Redmine, which could potentially contribute towards this desired outcome.

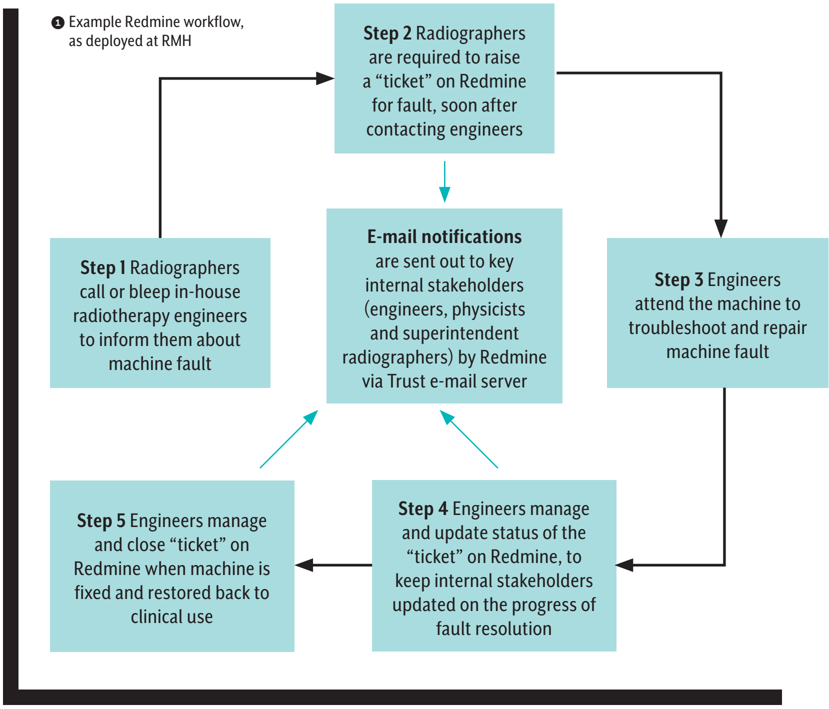
Redmine is a FOSS project management and issue tracking web application and is freely available to download for Windows, macOS, Linux and UNIX operating systems (OS). Redmine has already been adopted by a couple of radiotherapy centres in London; most prominently the Royal Marsden (RMH) site at Chelsea, as an in-house solution to track faults with linear accelerators. Plans have been afoot since early 2020 to develop and adapt a customised Linux-based version of Redmine to track radiotherapy equipment faults across three different radiotherapy sites run by Guy's and St Thomas' NHS Foundation Trust (GSTT), London as well.

Project background and system development

The inspiration to develop a customised version of Redmine for use in the GSTT radiotherapy department primarily came from attending a course in radiotherapy physics at the Institute of Cancer Research in March 2020. RMH radiotherapy physicist Richard Trouncer delivered a lecture on IT essentials in radiotherapy, where he briefly discussed the deployment of Redmine at RMH. We arranged a further face-to-face meeting to find out more and Richard, along with his colleague Steve Butler, kindly demonstrated how their Linux-based Redmine system (running off a virtual machine) had been incrementally developed and deployed at RMH since 2017, where RMH treatment radiographers were encouraged to raise an "e-ticket" on Redmine for any machine faults reported to the in-house radiotherapy engineers. The e-ticket status was then updated as the case progressed towards resolution, and e-mails sent out accordingly to notify relevant internal stakeholders (see to ❶ for an example workflow). This meeting provided enough information and inspiration to commence work on developing a similar e-ticketing system at GSTT, tailored specifically for use in the radiotherapy department.

The radiotherapy department at GSTT currently hosts eight Varian TrueBeam linear accelerators (including one STx linac for stereotactic treatments), three GE Discovery CT scanners, one Accuray TomoTherapy unit, one XStrahl 200 superficial unit, and one Elekta Flexitron HDR brachytherapy unit, spread out across three sites within the Greater London area. The oncology information system (OIS) in use at GSTT is Varian ARIA, and radiotherapy QA activities are logged and monitored using QATrack+.

Initially, a Windows-based version of Redmine was installed on a local PC in 2020, to get a feel for the software. Once familiar with the core features of Redmine, a decision was made to switch to a Linux-based (Debian) installation of Redmine on a higher specification standalone server PC, linked to the local area network (LAN) in the GSTT radiotherapy department. This was because Linux, by virtue of being an open-source OS, offered much more stability, flexibility and robustness compared to Windows. Furthermore, plugins would also need to be installed to extend the functionality of Redmine, and the plugin installation process was also subsequently discovered to be much easier on Linux, compared with Windows. The Docker platform was also utilised to "package" Redmine and its associated plugins into a "container" (which was a deviation from the RMH approach of using a virtual machine), as "containers" are essentially an industry standard for application and software development. This platform-as-a-service (PaaS) framework enables web applications to be containerised, deployed and accessed quickly on demand, via LAN and online "cloud" services.



❶ Example Redmine workflow, as deployed at RMH

Over the course of 2021, different versions of Redmine and its relevant plugins were installed and tweaked to find the most optimum overall configuration. The Redmine back-end database was selected to be MySQL during the installation process, as it is one of the most commonly used relational database management systems. Engineers, physicists and radiographers were allocated group-based user accounts, with differing levels of functionality and privileges as per their staff designation (e.g. engineers would have the highest level of privileges, whereas physicists and radiographers would only have the rights to raise an e-ticket, but not to change the e-ticket status for example). A free Redmine plugin called "Dashboard" in particular, which provides a visual overview of active e-tickets pertaining to radiotherapy machine faults, is able to be freely accessed by all staff groups to see the current status of the e-ticket. Different radiotherapy staff groups were informally surveyed via vox pop and shown the prototype version of Redmine, and the overwhelming response was that the new system was very much required in the department, with a Microsoft Access database

> **"THE RESPONSE WAS THE SYSTEM WAS VERY MUCH REQUIRED IN THE DEPARTMENT**

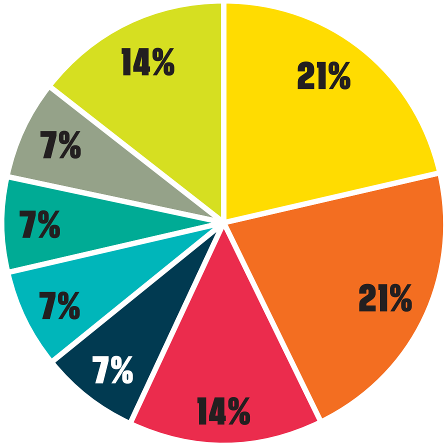
currently being used by engineers to maintain a record of machine faults since the early 2000s. The internal feedback was also used to develop and adapt the user interface (UI) incrementally as per clinical/engineering staff requirements. An additional goal of the GSTT Redmine project was to utilise a FOSS solution to initiate a transition towards a paperless department, by helping to eventually eliminate the current practice of recording machine faults and associated downtime in paper-based handover logbooks.

In November 2021, a two-week internal audit was conducted by GSTT Radiotherapy Physics, to record how many faults arose across 12 radiotherapy machines in the department ❷, which required 1st line intervention by either physicists or engineers ❸. The outcome of this audit was utilised to tailor the development of Redmine to help categorise faults better on different types of machines.

❷ Breakdown of number of GSTT RT machine issues over two-week internal audit

GSTT RT Machine	Total no. of faults
Varian TrueBeam G1	2
Varian TrueBeam G2	4
Varian TrueBeam G3	0
Varian TrueBeam G4	1
Varian TrueBeam G5	2
Varian TrueBeam G6	4
Varian TrueBeam Q1	1
Varian TrueBeam Q2	5
GE Discovery CT1	2
GE Discovery CT2	1
GE Discovery CT3	1
XStrahl 200 Superficial	4

❸ Pie chart breakdown of most common GSTT RT machine faults recorded during two-week internal audit



Proposed system rollout

New high-specification servers were ordered to supersede existing servers, and the final version of Redmine will be installed and hosted on these (via Docker). The Redmine e-ticketing system is anticipated to be rolled out by the second quarter of 2022, initially at the trust's smaller satellite cancer centre at Sidcup, before subsequently being rolled out at the larger main site at Guy's. Training sessions would be organised for all relevant staff groups, and the system would be expected to initially run in parallel with the existing radiotherapy engineering workflow during the initial transition phase, before eventually becoming the de facto method of managing machine faults.

Anticipated future development pathways

Although Redmine has been primarily developed at GSTT to track radiotherapy machine faults, the sheer number of free (and paid-for) plugins available in the Redmine library means that its use could also potentially be expanded to incorporate the accurate calculation of machine downtime. As the methodology used to analyse and calculate radiotherapy machine downtime at GSTT is rather complex, this is an avenue which is envisaged to be explored later on down the line, as it would also require the compilation of Python scripts to run downtime data calculations using the plugins. Other Redmine plugins are also potentially anticipated to be installed in the near future at GSTT to keep stock of radiotherapy spare parts inventory, as well as for asset management purposes. Another development pathway envisioned in the future at GSTT is the use of a Python-based FOSS web application called Grafana, which would integrate with Redmine/QATrack+ to allow the monitoring and analysis of key machine metrics and logs extracted from the Redmine/QATrack+ MySQL databases, and output these visually in terms of graphs and charts on a large centrally-based monitor, thus providing GSTT radiotherapy staff with real-time information about the performance and status of all radiotherapy equipment in the department.

Conclusion

Redmine, due to its off-the-shelf FOSS nature, has already shown that it can provide a zero-cost option to effectively manage radiotherapy machine faults across radiotherapy centres in the NHS, while also providing a potential solution for helping centres to transition towards a paperless future. Furthermore, the fact that its functionality can be significantly enhanced through a myriad of plugins, means that it can also be utilised by staff for many other useful functions too in a busy, modern day NHS radiotherapy department. ❍

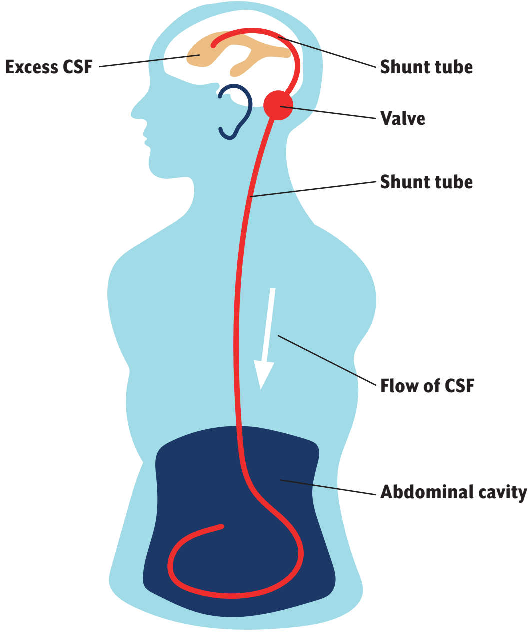
__Nino Manikandan__ and __Priesh Mistry__ are Senior Radiotherapy Engineers at Guy's and St Thomas' NHS Foundation Trust, London. *They would like to thank __Richard Trouncer__ and __Steve Butler__ for the inspiration and their time and GSTT Radiotherapy Physicists for providing permission to use their GSTT radiotherapy machine performance audit data in this article.*

HOW TO...

...safely scan a hydrocephalus shunt

Rebecca Stace and colleagues present a decision tree for determining between programmable and non-programmable cerebrospinal fluid shunt valves for the MRI physics community.

There has been considerable effort within the UK MRI Physics community to develop generic implant safety policies (GISPs). The process for this often involves an in-depth review of specific implant categories, followed by the completion of a risk assessment, which may be used to inform an MRI safety policy statement. This work aimed to develop a GISP for non-programmable cerebrospinal fluid (CSF) shunt valves used to treat patients with hydrocephalus. The in-depth review has highlighted the key challenge clinical MRI departments may face when patients present with these implants: identifying the CSF shunt valve as programmable or non-programmable. The answer may affect the circumstances under which the MRI scan can proceed. A decision tree, influenced by the in-depth review analysis, has been developed for this purpose and is presented here (overleaf) in the hope that it could benefit the MRI community.



❶ A basic shunt system

Clinical context of CSF shunt systems

CSF shunts are implanted to treat patients with hydrocephalus – a condition which results in the accumulation of CSF in the ventricles of the brain affecting four to six people per 1000. Shunt systems aid in restoring the balance of CSF. A basic shunt system comprises of a proximal ("ventricular") catheter, which is connected to a distal catheter via a one-way pressure valve ❶. The proximal catheter enters the ventricle space through a burr-hole in order to suction out excess CSF. The remaining parts of the shunt system are subcutaneously implanted and therefore entirely extracranial. The distal catheter extends from the valve to an absorption site, such as the peritoneal space/abdominal cavity, pleural space or right atrium, where it is reabsorbed. The shunt valve directs the flow of CSF away from the brain and regulates the pressure and flow rate. Theoretically, a valve can be placed anywhere along the course of the shunt system, but most are implanted proximally (i.e. at any height up the side of the head and towards the neck) or distally (i.e. pectoral or peritoneal region). A multitude of shunt components, in addition to the shunt valve and catheters, are offered by various manufacturers. These internal accessories may include reservoirs/pumping chambers, siphon control devices/gravitational units, connectors, and filters.

> "THE SHUNT VALVE DIRECTS THE FLOW OF CSF AWAY FROM THE BRAIN

Shunt valve: programmable vs non-programmable

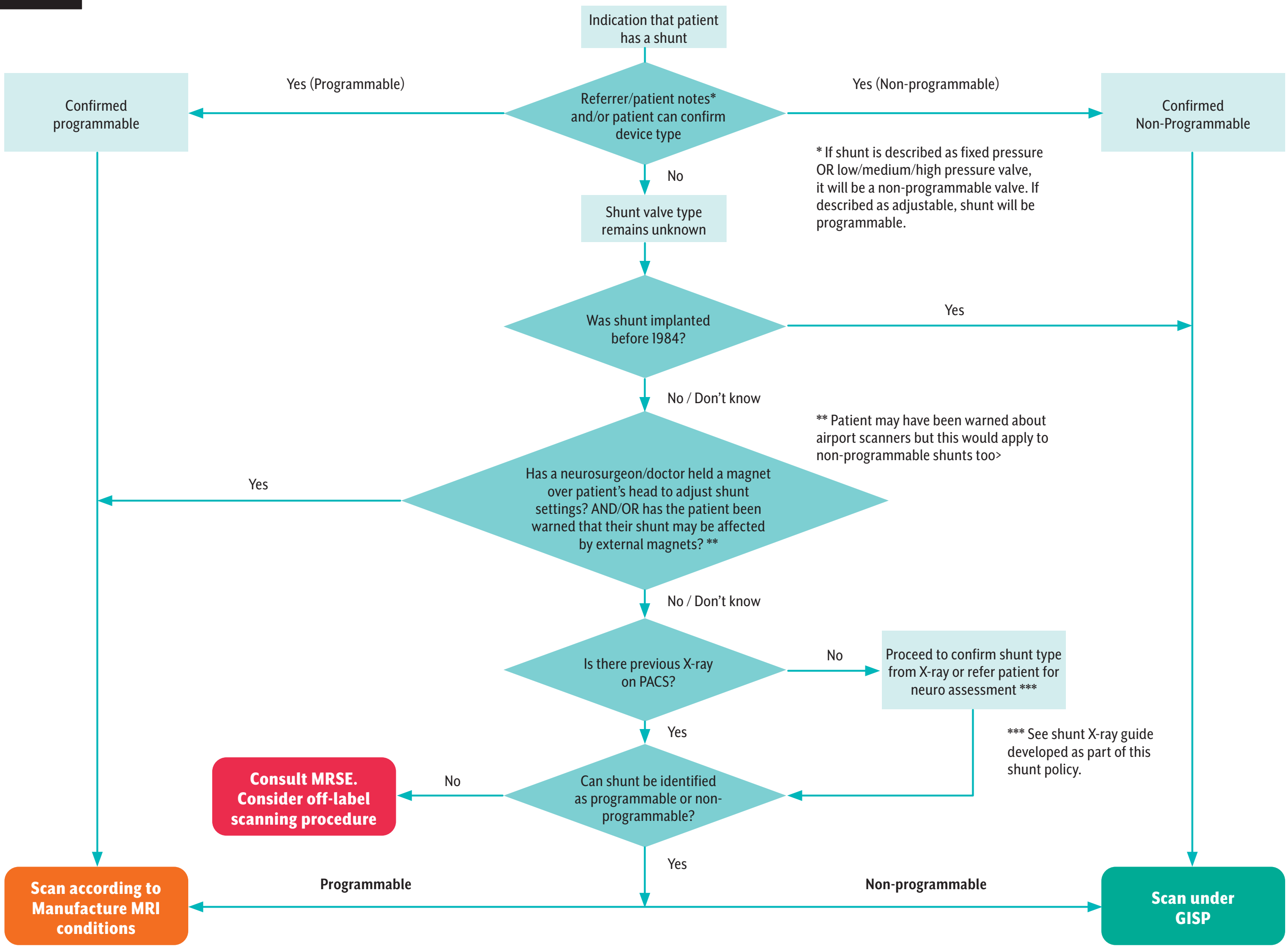
There are two different types of shunt valves that exist: fixed/mono-pressure ("non-programmable") and adjustable ("programmable").

Fixed pressure valves drain at a pre-defined rate (e.g. low-, medium-, or high-pressure), which is defined by the opening pressure of the valve. If this opening pressure is not suitable, there will be over or under-drainage of CSF and a neurosurgeon will have to surgically revise the shunt valve.

Programmable valves mitigate this invasive procedure by allowing the neurosurgeon to non-invasively adjust the valve setting using an externally applied (magnetic) programming tool. The Sophy valves (Sophysa) were the first programmable valves on the market and were introduced in 1984.

Unlike non-programmable valves, the programmable type comprises of magnetic components, which communicate with the external tool to alter the valve setting. As such, programmable shunt valves can be susceptible to environmental magnetic fields – patients are typically asked to stay away from sources of magnetic fields such as magnetic toys. This may not be true, however, for those programmable valves, which incorporate an in-built locking mechanism in

IMAGE: SHUTTERSTOCK



❷ A decision tree to assist in determining a patients CSF shunt valve type. MRSE = MRI Safety Expert

their design to prevent adjustments to the valve setting by external magnets other than the manufacturer's programming tool. Evidence provided by one manufacturer highlights that with over 380 exposures to a 3T magnet the locking mechanism prevented an unintentional change in the valve setting. Despite this, some shunts with an in-built locking mechanism still require pre- and post-MRI checks of the valve setting via the programming tool or X-ray imaging as a precaution and best practice, e.g. Codman Certas Plus. While others suggest there is a theoretical risk of a setting change if the patient's head undergoes a rotational movement in the presence of a powerful magnetic field (e.g. Sophysa Polaris). For valves manufactured by Meithke, pre- and post-MRI checks are not currently a requirement and, therefore, these can readily be scanned at many sites. For the Codman Certas Plus valve, the manufacturer can provide training to non-neurosurgical staff to use the associated programming tool for checking the valve setting – this mitigates the need for a post-MRI X-ray check. The typical appearance of various valve positions is provided from the manufacturers as part of the scan conditions helping to enable easy identification from X-ray. Given valves with inbuilt locking mechanisms have high resistance to a setting change, and that the shunt setting can be checked via X-ray, it opens the possibility for centres without direct neurosurgical support to scan patients with programmable shunts. In the unlikely event of a setting change, if arrangements are in place for follow up with a neurosurgical centre, then the risk to the patient is extremely low.

This process is potentially not overly burdensome since patients with programmable shunt valves typically have routine appointments with their implanting clinician if they require the valve setting re-adjusted.

Decision tree for differentiating between programmable and non-programmable

To manage patients where there is uncertainty regarding the nature of the valve the decision tree shown in ❷ was developed. Given the first programmable shunt was implanted in 1984 the implantation date can help inform if the shunt is non-programmable. Furthermore, given the key operational differences between programmable and non-programmable CSF shunt valves, certain questions can be put forward to the patient to assist with identification of the shunt valve type. These questions have been devised through discussions with neurosurgeons, shunt manufacturers and the peer-reviewed literature. Failing this, conventional radiography (or previous suitable imaging) may be performed and when done so correctly (film is shot perpendicular to the plane of the valve with the non-implanted side of the patient's head resting on the plate), it can help identify the valve type. A radiograph of a programmable valve will show a rotating structure i.e., a cam assembly. The configuration of this structure informs the valve setting which allows regulation of the opening pressure. This mechanism is absent in a non-programmable CSF shunt valve. Finally, given the adjustable valve mechanism utilises a magnet, there is potential for a ferromagnetic detector to identify cases where the patient has a programmable shunt potentially providing an additional method for identifying the shunt type.

"QUESTIONS CAN BE PUT FORWARD TO THE PATIENT TO ASSIST

Scanning non-programmable CSF shunt valves under a GISP

The in-depth review of non-programmable CSF shunt valves involved collating information from multiple MRI safety resources including MRISAFETY.com, MRI safety statements from shunt manufacturers, and peer-reviewed literature. Anecdotal and empirical data was gathered from further resources, such as the SMRT Technologist mailbase, UK MRI physics mailbase, the MRI safety Facebook page and a general internet search. Discussions with manufacturers and leading MRI safety authors have been considered in the process as well as work shared by other UK centres.

Our review has established the majority of known non-programmable CSF shunt valves to be MRI Safe or MRI Conditional up to 3T. MRISAFETY.com highlighted two shunt valves and an internal accessory with MR Unsafe labelling: a Holter type valve (type unknown), Hakim valve, and an unnamed right angle stainless steel ventricular shunt tube connector. Limited evidence in the literature accounts for this MRI Unsafe labelling with "slight ferromagnetism" seen at 1.5T for the shunt valves, and "measurable ferromagnetism" seen at 1.44T for the connector. The literature has further highlighted a potentially unsafe ventricular shunt catheter with metal connector that exhibited "evident ferromagnetism" at 1.5T. Empirical evidence highlights variations of the Holter valve have been scanned safely both locally (NHS Greater Glasgow and Clyde) and internationally (University of Leipzig, Germany) at 1.5T. No patient incident/injury related to the MRI scanning of a non-programmable CSF shunt system has been reported.

The most restrictive MRI conditional labelling limits identified in the review required a static magnetic field strength up to ≤3T, the spatial gradient to ≤720G/cm, and the SAR to ≤3W/kg. The GISP contains the same conditions but with a higher spatial gradient limit (consistent with modern day MRI scanners). It has been discussed in various forums that the t≤720G/cm limit is typically based around the limit of the testing equipment and hence scanning on higher MR systems with higher spatial gradients was deemed acceptable. A risk assessment was performed on the older MR unsafe shunt valves and accessories. It was decided to include these in the GISP given the poor evidence of the hazard level and the lack of reported incidents.

Conclusion

All programmable valves are MRI Conditional up to 3T but given some require pre and post MRI checks, the make/model should be identified and the manufacturer IFU consulted in order to inform of safe scanning conditions. The main concern with this shunt category is MRI induced alteration to the valve setting. It is therefore important to identify if a patient's programmable valve requires the valve setting to be checked pre and post MRI. Given modern programmable valves have inbuilt locking mechanisms, and setting can be checked via X-ray, there is potential for these valves to be scanned outside of specialist neurosurgical centres. Findings from the detailed evidence review of non-programmable shunt valves suggests it seems suitable to scan this shunt valve type under a generic policy.

***Rebecca Stace**, Clinical Scientist, Department of Medical Physics and Bioengineering, NHS Highland.* ***Jonathan Ashmore**, Principal Clinical Scientist, Department of Medical Physics and Bioengineering, NHS Highland.* ***Mike Hutton**, Consultant Clinical Scientist, Christie Medical Physics and Engineering, The Christie NHS Foundation Trust.*

GF
GENERAL FEATURES

ALL IS NOT AS IT SEEMS

COVID vaccinations and imaging

Clara Ferreira looks at the impact that COVID-19 vaccinations can have on ^{18}F-FDG PET-CT scans.

The development of COVID-19 vaccines has played a key role in protecting people in the pandemic, as shown by the substantial reduction of symptomatic COVID-19 rates recorded following the administration of the first dose. The vaccines against COVID-19 were developed and had their efficacy proven within a year of the beginning of the pandemic – these are considered scientific breakthroughs.

^{18}F-FDG PET-CT scans are useful for providing accurate staging in several types of cancer – especially for accurate nodal staging, which is important to define treatment as per indication of several guidelines – and monitor the response to the treatment. The radiopharmaceutical ^{18}F-FDG is uptaked by the GLUT receptors providing information about the glucose metabolism, which allow us to visualise malignancies, infection/inflammation and characterise lesions metabolism. The non-specific or inflammatory uptake has been a limitation of ^{18}F-FDG PET-CT.

In PET-CT with ^{18}F-FDG it is possible to observe a specific pattern in the imaging of patients infected with COVID-19 – increased uptake in the lung lesions with segmental ground-glass densities and plaques, in normal-sized or slightly enlarged lymph nodes and in the bone barrow and spleen.

Soon after, while reporting ^{18}F-FDG PET-CT studies, uptake in axillary, supraclavicular and cervical lymph nodes associated with COVID-19 vaccination was identified, which is not surprising as ^{18}F-FDG is not tumour-specific and accumulates in infectious tissue, inflammation and other hypermetabolic lesions. Lymphadenopathy has been reported with several other types of available vaccines, such as, H1N1 and human papillomaviruses (HPV) and the uptake increase can cause false-positive results when administered less than 14 days before the scan, with the highest probability being when the scan is performed less than eight days after the COVID-19 vaccination.

However, the impact of the COVID-19 vaccines on ^{18}F-FDG PET-CT scans was higher than was expected.

Several case reports and small cohorts studies have already identified through radiology images the identification of vaccine-associated lymphadenopathy post-anti-SARS-

CoV2 vaccine; a recent report explores the concern of accurate imaging in view of lymphadenopathy associated with vaccination suggesting the ideal times between vaccination and the ^{18}F-FDG PET-CT scan, indicating that the scan should be postponed to six weeks after vaccination. Unfortunately, this situation is problematic in oncological patients.

In this document, you can find what has been published in the literature until now and, hopefully, this will help you to understand the theme better and to help your department in these difficult times.

"UNFORTUNATELY, THIS SITUATION IS PROBLEMATIC IN ONCOLOGICAL PATIENTS

Materials and methods

A review of the available English-language literature was conducted using the databases MEDLINE and Cochrane library (2019 to 2022) was search using the following terms: "Positron Emission Tomography" or "PET-CT" and "^{18}F-FDG" or "FDG" and "COVID-19 vaccine" or "COVID-19". The results indicated a total of 137 scientific articles and reports; most of the articles were related to COVID-19 infection and not associated directly to its vaccination. After reading the abstract of the papers, a total of 21 articles were considered for analysis.

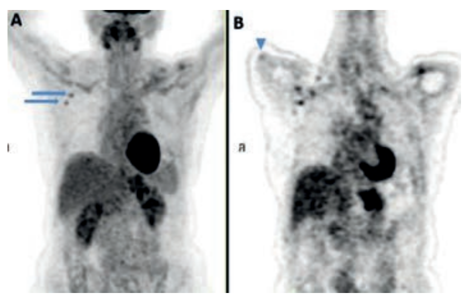
Results and Discussion

The most notorious information about the ^{18}F-FDG PET-CT imaging after COVID-19 vaccination was related with the accumulation of ^{18}F-FDG in axillary, supraclavicular and cervical lymph nodes located in the ipsilateral deltoid to the vaccination site – which indicates immunoreactions that are activated by inflammatory cells due to a immune response, this way, a high number of monocytes in lymphoid tissue increases leading to lymph nodes swelling (lymphadenopathy) and, consequently, to an increase in ^{18}F-FDG uptakes.

This type of lymphadenopathy was reported within two to four days after vaccination, with an average duration of approximately 10 days; nodal uptake tends to occur within seven days after vaccination and generally disappears by 12-14 days, but it can remain for four to six weeks, or seven to 10 weeks after the injection. The impact in ^{18}F-FDG scans ended up being higher than expected, considering the size and number of lymphadenopathy, which is considered relatively severe because it was able to be identified with palpation and/or visual inspection. The lymph node sizes vary from normal to moderately increased and presents thickening of the cortex and fatty hilum – suggesting benign lesions. However, shortly after vaccination, lymph nodes can present abnormal size and loss of fatty hilum, which can be considerate malignant. The lymph nodes on the injected site are mostly affected, but contralateral lymph nodes can also show ^{18}F-FDG uptake; therefore, the findings can lead to misdiagnosis in the evaluation of malignant and inflammatory disease, specially regarding breast cancer, melanoma, lymphoma, sarcoidosis and high-grade or aggressive malignancies and those requiring urgent initiation of treatment because they have a high probability of invasion around these sites.

The ^{18}F-FDG uptake in the lymph nodes was much greater in the second vaccination; on the other hand, lower uptake was associated with older age, immunosuppressive treatment and hematologic disease. A higher ^{18}F-FDG uptake was showed for the Moderna vaccine in comparison with Pfizer vaccine. It was also noted that vaccines based in mRNA vaccines appear to stimulate immune activity to a greater degree than do vaccines based on traditional biotechnologies.

The existence of ^{18}F-FDG uptake is small axillary lymph nodes is a common feature after vaccination against influenza and another diseases; in the COVID-19 vaccine case, the reaction is more severe and it is present for longer; this way, it is thought that the reason may be related to the nature of mRNA



❶ The ^{18}F-FDG PET-CT scan of a 72-year-old female after treatment for follow-up. The image A is the maximal intension projection showing moderately increased uptake in the right deltoid muscle (blue arrows) of normal size; image B shows the focally increased uptake in the right deltoid muscle corresponding to the recent COVID-19 vaccine (Eifer and Eshet, 2021).

IMAGE: GETTY

biotechnology vaccines considering that they can lead to increased immunogenicity compared with the traditional vaccines.

In the research published last year, the incidence of vaccine-associated hypermetabolic lymphadenopathy was 36.5% among all subjects who were vaccinated, but it became significantly higher after the second vaccination (45.8%) compared with the first vaccination (26.3%), The node size, uptake in lymph nodes beyond level 1 and the site of vaccination were more prominent in the second vaccine.

After the first vaccination, the incidence of vaccine-associated hypermetabolic lymphadenopathy was higher at six to 12 days after vaccination, compared with the visualisation at the first five days and at 13 days. After the second vaccination, the incidence and grade of vaccine-associated hypermetabolic lymphadenopathy were highest in the first six days, decreasing gradually over time and becoming significantly low at more than 20 days after vaccination; on the other hand, other research mentions that the nodal uptake can be visualised even at 70 days after the vaccine administration. The group with highest incidence and highest grade in the first vaccination was in subjects aged $\leq$ 62 years old; while in the second vaccination, there was a higher incidence and grade in the subjects $\leq$ 64 years old.

The intramuscular mRNA COVID-19 injection in the deltoid muscle also leads to increased ^{18}F-FDG uptake shortly after the infection; the site of other vaccines manifests as a relatively small and slight ^{18}F-FDG uptake shortly after the vaccine administration; on the other hand, following the administration of COVID-19 vaccine, a moderate uptake is visualised as a broad area indicating a high degree of inflammatory change in the deltoid muscle –

"INFORMATION IS STILL LACKING REGARDING DURATION AND PREVALENCE

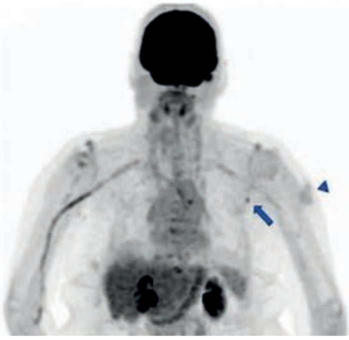
however, it is unclear if the uptake is related to the pain and/or swelling at the injection site. In 2021, a case report was published of a 72-year-old female who performed 18F-FDG PET-CT for follow-up after performing left lumpectomy and sentinel lymph node biopsy and adjuvant treatment for HER2+ breast cancer in 2017 ❶.

The patient was vaccinated 10 days prior to the scan on the right deltoid muscle with the Pfizer-BioNTech COVID-19 vaccine. The findings are likely related with the recent vaccination and not seen as a contralateral axillary lymph node involvement in breast cancer. Another example comes from a case report on a 76-year-old female with oligosecretory myeloma disease underwent follow-up assessment with 18F-FDG PET-CT ❷.

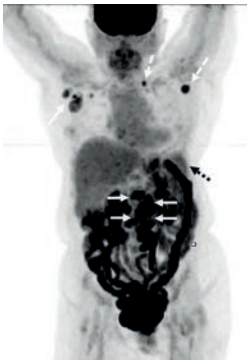
The patient had the COVID-19 vaccination with Oxford-AstraZeneca in the left upper arm two weeks before the scan, which keeps in line with the findings on this scan.
A case report published in 2021 reveals a 51-year-old man with New Hodgkin's lymphoma who has been vaccinated on the left deltoid three weeks prior ❸.

It is also possible to observe ^{18}F-FDG uptake in the spleen after COVID-19 vaccination, which has also been observed in ^{68}Ga-DOTA-TATE, ^{11}C- and ^{18}F-choline, ^{68}Ga- and ^{18}F-PSMA scans. It is visualised as a diffusely increased splenic uptake; sometimes associated with a systemic immune response following vaccination. In 2021, a case stud was published of a 75-year-old man with prostate cancer and biochemical recurrence underwent 18F-choline PET-CT scan for disease assessment ❹.

The patient indicated that he had received the Oxford-AstraZeneca COVID-19 vaccination in the left upper arm three days before the scan, which justifies the uptake detected in the



❷ The ^{18}F-FDG PET-CT maximal intensity projection demonstrating a focal uptake in the left axilla (blue arrow) and defined subcutaneous uptake in the left arm (blue arrowhead) (Nawwar *et al*, 2021a).



❸ ^{18}F-FDG PET-CT scan of a 51-year-yold man with Hodgkin's lymphoma. The maximal intensity projection demonstrates ^{18}F-FDG avid lymphadenopathy above and below diaphragm (white arrows). It is unclear if the left axillary and supraclavicular uptake (white dashed arrows) are from the recent COVID-19 vaccination, which was administrated in the left deltoid three weeks before the scan. It is possible to visualise increased uptake in the spleen (black dashed arrow), more avid than liver, which could be either understood as caused by vaccination or disease involvement (McIntosh *et al*, 2021).

❹ Maximal intensity projection of 18F-choline demonstrates mild defined uptake in the left arm (orange arrow) and areas of intense focal uptake in the left axilla (blue arrow). The radiopharmaceutical was administered in the right antecubital fossa, contralateral to the COVID-19 vaccine (Nawwar *et al*, 2021b).

left deltoid and the nodal uptake considered to be reactive in relation to the vaccination.

This way, in the imaging studies performed for the management of patients, it is important to have information regarding the timing of the COVID-19 vaccine, which can be done by a preliminary vaccination anamnesis by the imaging department staff regarding the vaccination status – this might be an effective method to ensure that the scans are booked at the most appropriate time in order to increase the accuracy of diagnosis. It is also important to pay attention to stable patients on treatment or surveillance – as their scans can be ordered far in advance (the request could be submitted months to a year prior the scan happened, which can lead to a conflict between the patient's vaccination and imaging). Also, some patients choose to defer routine surveillance scans due to the ongoing pandemic and, by now, are overdue for scans at the same time that vaccination became available for them. Hopefully, in the future, the oncology teams will be more aware of the patient vaccination status in order to provide guidance in the administration site and help with the timing of a planned imaging.

According to research from 2021, PET-CT scans with ^{18}F-FDG should be performed immediately after or four to six weeks after vaccination. However, if the scan is scheduled for immediately after the vaccination, the patient might ask to re-schedule considering the common side effects (such as fever, nausea, chills, headache and tiredness). Some research recommends performing ^{18}F-FDG scans five days after the first vaccine dose, in the third or just before the administration of the next dose; if the booster vaccine dose was already administered, the time recommended is at least three weeks after.

However, information is still lacking regarding the duration and prevalence of post-vaccination imaging findings.

Conclusion

This feature highlights a potential major pitfall in ^{18}F-FDG PET-CT in the next few months, and potentially years, considering the phase of massive immunisation against COVID-19 and possible future boosters.

Considering the impact on ^{18}F-FDG PET-CT scans, it is important to manage the timing of the scan with respect to the date of vaccination in order to avoid potential disease upstaging and over-treatment. Research emphasizes the importance in patients with breast cancer and axillary lymphoma, considering that it can lead to equivocal reports.

The ^{18}F-FDG PET-CT should not be delayed when clinically indicated or urgently needed. If possible, the imaging scans should be performed before the vaccination in order to avoid overlapping findings. If not possible, most research advises that the scan is performed no sooner than two weeks after COVID-19 vaccination, but some research recommends four to six weeks is a more optimal timeframe, which might not be possible all the time, considering that it can lead to a delay treatment initiation.

Ideally the COVID-19 vaccine should be administered in the contralateral arm to the side of the disease, especially in patients with breast cancer, axillary lymphoma and malignancy in the upper limb.

Finally, it is important that radiologist are aware of the clinical and imaging patterns of the immune response to vaccination – the local benign and transient side effects – especially in the context of COVID-19 pandemic. It is also important to reassure patients that there is no risk of cancer stimulation, especially in women undergoing follow-up for breast cancer, having patient anxiety in consideration.

__Clara Ferreira__ is a Senior Nuclear Medicine Technologist in University Hospitals Coventry and Warwickshire NHS Trust.

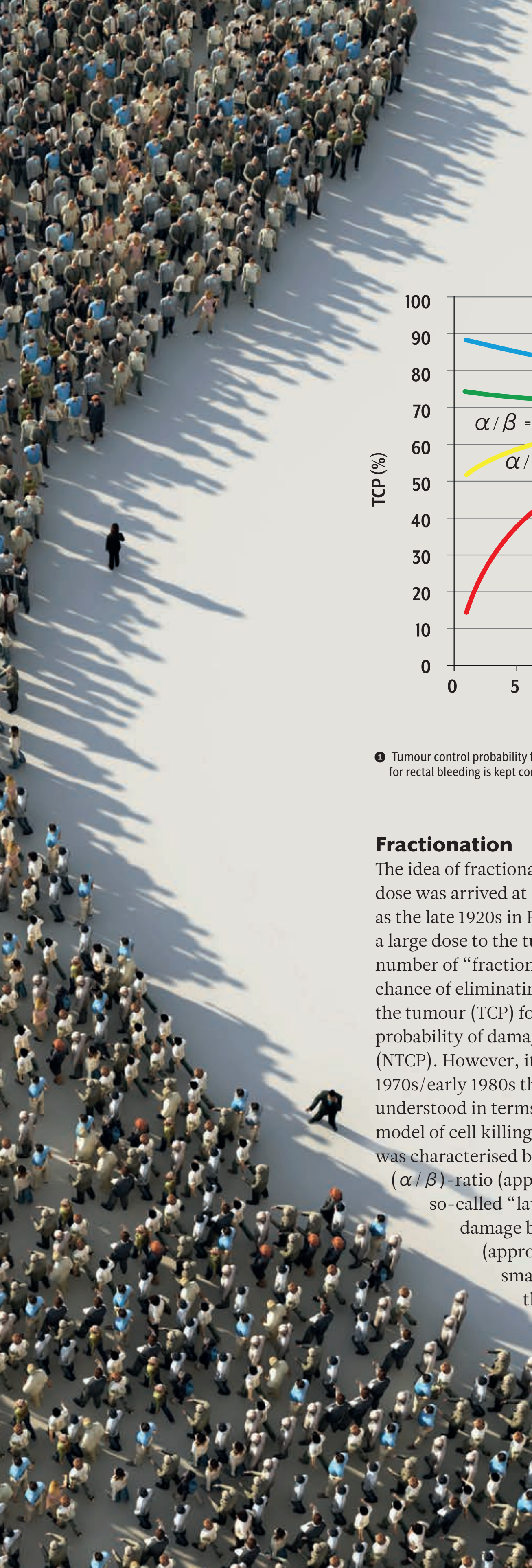
References were supplied and can be requested by emailing rob.dabrowski@redactive.co.uk

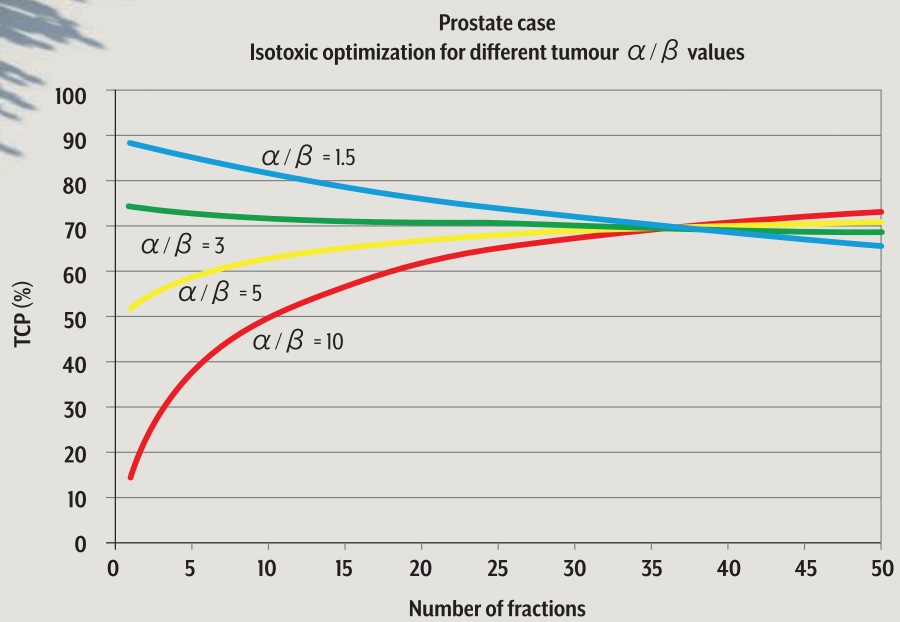
Alan E Nahum argues that a significant increase in fraction size would enable a much quicker elimination of the COVID-19-induced treatment backlog.

RADIOBIOLOGICAL MODELLING

How to reduce the COVID-19 radiotherapy backlog

The aim of radiotherapy is to "kill" all the clonogenic cells (i.e. those with the potential for further division) in a patient's tumour. External-beam radiotherapy (EBRT) from a linear accelerator (i.e. bremsstrahlung created by megavoltage electrons hitting a tungsten target), the most common form of cancer treatment by (ionizing) radiation, is almost always administered in a large number of so-called "fractions"; thus a total dose of typically 70 Gy is delivered in 35 fractions of 2.0 Gy, one each weekday, with a break at weekends.





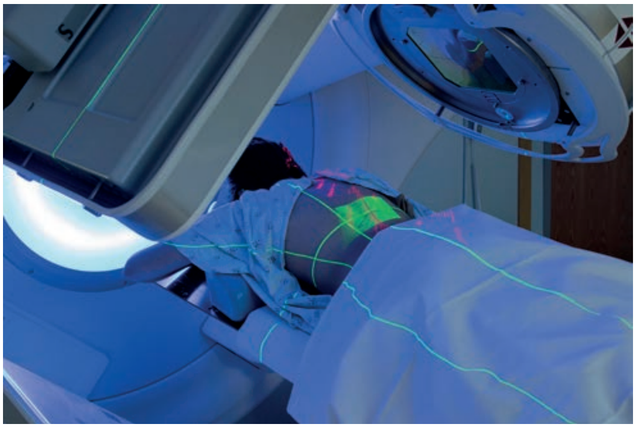
❶ Tumour control probability for varying tumour α/β (nominally for a prostate tumour) as the number of fractions is varied while the NTCP for rectal bleeding is kept constant at the low value of 4.3% (adapted from Uzan and Nahum, 2012).

Fractionation

The idea of fractionating the total radiation dose was arrived at empirically as far back as the late 1920s in France. Delivering a large dose to the tumour in a large number of "fractions" resulted in a decent chance of eliminating (or "controlling") the tumour (TCP) for an acceptably low probability of damaging normal tissues (NTCP). However, it wasn't until the late 1970s/early 1980s that fractionation was understood in terms of the linear-quadratic model of cell killing – tumour cell killing was characterised by a high alpha/beta (α/β)-ratio (approximately 10 Gy), so-called "late" normal-tissue damage by a low α/β-ratio (approximately 3 Gy). Thus small fraction sizes (of the order of 2 Gy) were believed to maximise TCP for an acceptably low NTCP; fraction sizes of 2 - 3 Gy became the norm in the "First World". Needless to say, a course of radiotherapy delivered at the rate of five sessions a week (Monday to Friday) from four to as many as seven weeks, depending on the type of tumour, has significant resource implications.

Challenges to this 2-Gy orthodoxy began to appear from the late 1990s. By comparing EBRT outcomes with those from implanted-seed low-doserate brachytherapy, in 1999 Brenner and Hall concluded that the α/β-ratio for prostate tumours could be as low as 1 Gy. However, by taking account of tumour hypoxia, in 2003 Nahum *et al* showed that the EBRT vs Brachy local-control data was consistent with $\alpha/\beta \approx 8$ Gy. Fast forwarding to the present, a growing body of data on tumour local-control rates is consistent with a relatively low α/β-ratio for both prostate and breast tumours.

Setting aside treatment orthodoxy, how might we expect the tumour control probability (TCP) to vary with the number of fractions, while keeping the probability of (late) complications (NTCP) at an



acceptably low value? Figure 1 shows how TCP varies with fraction number, for a range of tumour α/β, while keeping normal-tissue complication rate at an acceptably low 4.3%.

Fewer, larger fractions

During the last two decades extensive tumour-control data from prostate- and also breast-tumour EBRT have demonstrated that α/β for these respective tumours is significantly lower than the 10 Gy assumed in earlier decades: ≈ 2.7 Gy for prostate and ≈ 3.5 Gy for breast. This suggests that these tumour types can be treated with significantly fewer, larger fractions. Additionally, for the radiotherapy of early-stage non-small-cell lung tumours it has been demonstrated both clinically and theoretically that fraction sizes far larger than 2 Gy can be safely delivered. In this case, however, the reason is the strong volume dependence of the pneumonitis rate (in the normal lung tissue); α/β for the lung-tumour clonogens is believed to be ≈ 10 Gy.

What has the rather "nerdy" radiobiology described above to do with the COVID-19-induced treatment backlog in radiotherapy? Firstly, delivering radiotherapy with fewer daily fractions would immediately increase the number of complete radiotherapy treatment courses in a given time period – and increasing the dose per fraction would only have a marginal impact on the time per patient treatment. Secondly, as has been argued above, for breast, prostate and a significant fraction of (non-small-cell) lung tumours, which together constitute a large fraction of the workload in radiotherapy departments, the number of daily fractions could be significantly reduced, with at most only a marginal reduction in tumour control rates compared to the current regimens of 4-7 weeks of 2-3 Gy fractions. Most importantly, a significant increase in fraction size (and thus a reduction in the overall time per radiotherapy course) would enable a much quicker elimination of the COVID-19-induced treatment backlog. ◘

__Alan E Nahum__ is a visiting professor at the Liverpool University Physics Department and an IPEM Fellow.

HEALTHCARE TECHNOLOGY IN THE FUTURE

The role of the engineering workforce

We hear the key takeaway messages from a virtual event that looked at the future of the clinical engineering workforce.

At the end of last year, more than 400 of our healthcare science colleagues came together (virtually) to support the Clinical Engineering Hackathon. This event was designed to bring together the healthcare engineering community and use their breadth and depth of knowledge to create a vision of healthcare engineering for the future that will support high-quality, technology-enabled, patient-centred care, so we can truly fulfil our promise to work at the limits of science to save lives and improve health. Through a combination of thought provoking presentations and breakout rooms, we worked together to explore some key questions:

- **What is the blueprint for the future – what will a good engineering service look like?**
- **How do we ensure our engineering services can drive and support advances in patient care?**
- **What will the future workforce need to look like? What would a good career framework look like? How do we ensure we have enough people, with the skills they need, in the right place?**
- **What training and education pathways will we need to deliver this? How do we look after the wellbeing of our staff, to tackle discrimination, support diversity and inclusion, and offer our staff the development opportunities that allow them to develop and remain interested in a lifelong career in healthcare or related fields?**

Professor Dame Sue Hill DBE, highlighted the importance of our Engineering workforce during COVID-19 and moving forwards. The presentations from Colin Gibson, Professor Tony Young,

"THE REAL SUCCESS WAS DUE TO THE ENERGY OF THOSE IN THE 18 BREAKOUT ROOMS

Matthew Birchmore and Richard Scott were thought provoking, moving and inspirational. We heard about developments in services and how personal experiences lead to a drive to improve healthcare, how to seize the day as a clinical entrepreneur, leadership opportunities and how to support staff to step away from the bench and develop their skills and capability to improve and lead services. Finally we explored how we can be innovative in workforce development and training and think differently to create the workforce for the future.

Breakout rooms

However, the real success of the day was due to the contribution and energy of those in the 18 breakout rooms. Our 428 registrants came from a diverse range of services and roles (295 job titles), and from all regions and all four nations, as well as outside the UK. Engineering staff of all levels, from apprentices to heads of departments, attended and contributed to the discussions. This provided breakout rooms with diversity and a balance of fresh eyes and experience, which supported discussion and debate, and the generation of new ideas. The day ended with a "popcorn" question, asking all to put a word or phrase that described what they were going to take from the day (see below for a selection of responses).

Critical to the success of the event were:

- **Our facilitators, who showed great leadership, skilfully guiding the conversations to keep on track and making sure that everyone had a voice**
- **The "collectors" who pulled together a record of the themes**
- **The CSO FMLM Fellows, who supported Richard Scott and Claire Greaves to design and deliver the event**
- **The Regional CE Network Leads and the hackathon Task and Finish Group**
- **The CSO programme team and PCC.**

The next steps are to pull together all the findings into a report with targeted recommendations, to disseminate the findings widely and to work with key stakeholders to put in place systems and structures to ensure these are implemented.

A senior member of the profession commented: "Given the much higher profile that clinical engineers have achieved as a result of their remarkable and tireless efforts during the pandemic, this event and its follow up have the potential to be a profession-defining moment."

Claire Greaves, Chief Scientist and Clinical Director for the Science and Technology Pathway. Honorary Associate Professor, University of Nottingham Medical School
Angela Douglas MBE, Deputy Chief Scientific Officer, Office of the Chief Scientific Officer, NHS England and NHS Improvement
Professor Richard Scott, Director of Medical Physics and Bioengineering, UHBW NHS FT. Royal Academy of Engineering Visiting Professor (in regulated medical technologies), Heriot Watt University
Eleanor Holden, Clinical Fellow, Office of the Chief Scientific Officer, NHS England and NHS Improvement. Medical Physicist, Guy's and St Thomas' NHS Foundation Trust
Zoë Clarke, Clinical Fellow, Office of the Chief Scientific Officer, NHS England and NHS Improvement.
Lead Healthcare Scientist, Barnsley Hospitals NHS Foundation Trust

WHAT WILL YOU TAKE AWAY FROM THE DAY?

- Sense of community and common goals
- Champion more what we do with a desire to innovate more
- Inform staff of the opportunities and encourage them to use them
- Networking and willing to improve and grow
- Campaign within my trust
- The breath of views
- Establish central resources to support people with innovation
- Always stay at the edge of the comfort zone
- Good things are happening in clinical engineering – well done
- I am going to reach out to the fabulous colleagues I met today
- A workforce that wants to work together
- The quality of people that we have in this sector
- Leadership at all levels
- Sharing ideas between organisations
- A huge and well-motivated workforce
- Inspiring to see so many clinical engineers who are like minded
- Cross-profession learning opportunities
- Shared challenges, people's positivity, resilience and determination
- Experience shared is never lost
- Motivation
- Opportunities to think seriously about the future of the profession
- The importance of working together and not in silos.

Experience shared is never lost, lots of perspectives taken on board

Everyone cares about the future

Be proud of what we do

EQUIPPING THE WORKFORCE

The future of nuclear medicine

Robin Mark McDade, an Advanced Specialist Clinical Technologist from Glasgow Royal Infirmary, on training and the nuclear medicine workforce.

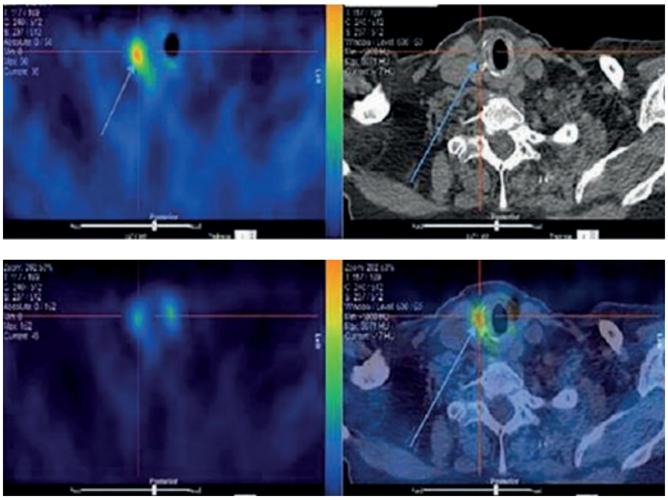
Rapid advancements in computed tomography (CT) in nuclear medicine (NM) have outstripped a co-ordinated response in guidance, standards and education. Hybrid techniques continue to redefine practice; confusing roles during an existing crisis in the provision of competent operators. This results from massively increased demand, which will continue to increase as the Richards report has recommend the upgrade of many NM imaging facilities (gamma cameras) to hybrid systems. The IPEM Diploma in Technology has recently updated its curriculum to include hybrid imaging (positron emission tomography CT and single photon emission computed tomography CT) as required competencies.

Drivers for change

In 2016, the Society of Radiography addressed confusion in the workforce stating they “do not encourage the practice of NM staff requiring a ‘CT-trained radiographer’ to make a CT/X-ray exposure on their behalf during an NM examination”. The society went on to call for an “appropriate development of Scope of Practice for Technologists regarding CT in NM.”

IMAGE: ISTOCK

Clinical demand for hybrid procedures has grown relentlessly. PET-CT referral rates have doubled every five years. Growth in SPECT with associated CT grew by 415% in a five-year period. Neither the Register of Clinical Technologists (RCT) Scope of Practice, nor the PTP Programme (PTP) curriculum specifically feature computed tomography competencies and a hybrid skill-set. The omission of CT competencies has led to an absence of CT-skills among newly qualified Clinical Technologists. IPEM notes: "While the PTP curriculum and the RCT Scope of Practice cover many of the areas of hybrid imaging required by clinical demand, it is not sufficiently explicit in its coverage of knowledge, understanding and skills such that trainees exit with sufficient competencies."



❶ Excerpts from the portfolio of a former trainee, Allan Laird, who was enrolled on the IPEM clinical technologist training scheme.

UK National Occupations Standards (NOS)

The UK Commission for Employment produces NOS, recognised by employers as a "clear, concise and consistent articulation of requirements for occupational competence". A NOS is a "document that describes the knowledge, skills and understanding an individual needs to be competent at a job. They present a framework for training, education design, assessment, and accreditation". NOS regarding PET-CT and SPECT-CT were published in 2019. A gap analysis of these NOS, the PTP curriculum and the RCT Scope of Practice, resulted in a new additional curriculum. From October 2021, satisfactory demonstration of these additional competencies is required for the completion of the IPEM Dip-T in Nuclear Medicine.

IPEM impact

Competing modalities such as CT & MRI draw the radiographer graduates from NM. The SoR recommends a PG-Diploma as entry level for NM, disincentivising new graduates from the workforce. The disparity in curricula between radiography and the PTP, where NM-specific modules provide a significant requirement for workplace training, explains this stance. Many employers across the UK choose the IPEM Dip-T to bridge the knowledge and skills gap for graduate diagnostic radiographers into NM. Therapeutic radiographers have also been using Dip-T as an onramp. However, while diagnostic radiographer graduates have the necessary education and skillset regarding CT, the SoR does not advocate that a therapy radiographer can effectively work as a diagnostic radiographer regarding CT practice. This lack is now addressed via the Dip-T for NM.

The Dip-T remains the gateway to registration with the RCT, accredited by the Professional Standards Authority (PSA). This is equivalent to the PTP programme and the Academy of Healthcare Science (AHCS) register. The RCT numbers its active NM registrants as 633, while worryingly the AHCS register has 13, at the time of writing. The availability of PTP NM programmes continues to diminish nationally due to poor recruitment, difficulties with placement capacity and systemic issues, e.g. funding. The IPEM scheme due to increasing demand, successfully doubled the number its external moderators (EM) in 2020. An EM's role is to: examine candidates' clinical practice in their workplace, mark their portfolios - which capture evidence of competence across the piste, perform their final viva, provide support and feedback to accredited training centres, and submit evidence of examination to IPEM ratification panel. Despite the difficulties during COVID-19, 2021 has already seen a 100% increase in candidates with more centres applying for accreditation.

> PET-CT REFERRAL RATES HAVE DOUBLED EVERY FIVE YEARS

IPEM's scheme aims to satisfy UK NOS via a work-based scheme providing a tailor-made solution to the NM workforce. Providing employers, a bridge for radiographers into NM practice, unifying the skillsets required for modern NM practice from clinical technologists (science graduates), while providing an on-ramp for apprentices. --The schemes measure of success is the confident, competent operators it forms and their advancement upon obtaining the Diploma. I would encourage centres of excellence not already using the training scheme to consider enrolling on our accredited training centre process.

AN IPEM TRAINEE PERSPECTIVE

Allan Laird describes his experiences on the IPEM Clinical Technologist Training Scheme and the career progression opportunities it provided.

I was enrolled on the IPEM Clinical Technologist Training Scheme (Nuclear Medicine) for two years, from 2018 to 2020.

The training scheme delivers a high-quality and structured framework that through peer-reviewed training and externally marked assessment, provides an excellent platform to build the necessary practical, theoretical and personal skills needed to be a successful clinical technologist. It also provides a direct pathway to RCT registration.

The training scheme is intensive, demanding and requires the trainee to put in a significant amount of work, both at work and at home. Whilst this may sound daunting, from my own experience this aspect of the scheme taught me many valuable skills that I have taken with me as I progress my career. There is a real importance on structuring and planning your workload, working to deadlines, documenting your learning and reflecting on your practice. All of these things remain critical components of a technologist's career as they progress. This for me is one of the stand-out benefits that the training scheme provides.

The delivery of the scheme itself can be tailored to help fill specific gaps in knowledge and experience that trainees may have upon starting in their post.

A good example would be from my own experience when joining the NHS and starting in my band 5 post, my qualification coming in was in Physics. So whilst I may have had a more solid footing in the theoretical and scientific aspects of nuclear medicine, I was significantly lacking in the anatomy and physiology aspects of the role.

To address these short comings, part of my additional and supplementary training was geared towards not only the fundamentals of anatomy and physiology, but also anatomy in cross section; which is more important than ever for clinical technologists as we continue to forge ahead in a hybrid imaging landscape.

This was achieved by enrolling on two modules from the MSc nuclear medicine degree course with the UWE Bristol. The courses, whilst challenging, provided me with a level of knowledge and understanding that has made me a more confident and skilled technologist.

This type of supplementary training can be achieved in many forms, from e-learning courses, local college courses, right up to MSc level at an approved institute, such as UWE Bristol.

Upon successful completion of the training scheme, trainees are in an excellent position to advance to the next stage in their career. For me, that was moving into a band 6 post in nuclear cardiology at Glasgow Royal Infirmary, where I have since been heavily involved in the introduction of the department's new cadmium zinc telluride (CZT) gamma camera and single photon emission computed tomography (SPECT) coronary flow reserve (CFR) service.

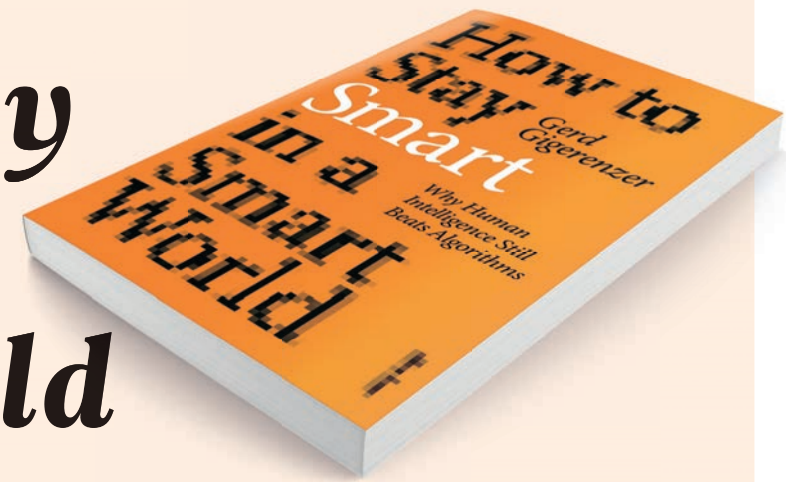
As well as career progression, it also opens up the opportunity of moderation within IPEM, where the experience and knowledge gained throughout the training scheme can be used to carry out the role of external moderator, responsible for the assessment of new trainees.

IMAGE: ISTOCK

__Allan Laird__ is a Specialist Clinical Technologist at Glasgow Royal Infirmary. For more information on IPEM training courses, visit __ipem.ac.uk/training-workforce__

BOOK PITCH

How to Stay Smart in a Smart World



Psychologist **Gerd Gigerenzer** on the ideas behind and the content within his new book.

Why can AI win at chess but not find the ideal mate? Are self-driving cars just down the road? Are we headed for a surveillance society? When navigating through a world populated with algorithms, there are two general principles to help us distinguish between what AI can actually deliver and what is in the realm of techno-religious fantasy.

AI enthusiasts who proclaim that our digital assistant will soon turn into a superintelligence that surpasses all humans clash with critics who brand tech companies as evil surveillance capitalism. Yet both share the same belief in the near-omniscience of AI.

Both factions overlook that computing power goes a long way for some kind of problems, but not for others. To date, the stunning victories of AI have occurred in well-defined games with fixed rules such as chess and Go, with similar successes for face and voice recognition in relatively unchanging conditions. The stable world principle says that complex algorithms work best in well-defined, stable situations. Humans are a main source of uncertainty, which explains why algorithms have little success in predicting whether a defendant will commit another crime or in finding the ideal partner for life.

Even if algorithms do not deliver what is advertised, they can alter our behaviour and values. Courtship, for instance, adapts to software. Quite a few people who found the partner of their dreams nevertheless cannot stop opening Tinder and looking for someone better. Or take the promise of self-driving cars that are able to drive everywhere and in all traffic conditions without any human backup. Instead, something more fundamental will likely happen: we will adapt our behaviour and our environments to the limited capabilities of automated cars by creating a stable world for them. That may mean banning human drivers from parts of a city and walling its streets off from pedestrians and bikers. In general, the adapt-to-AI principle says that in order to improve the performance of AI, we need to make the environment more stable and our behaviour more predictable.

> **"ALGORITHMS WORK BEST IN WELL-DEFINED, STABLE SITUATIONS**

Many citizens of democratic countries are disconcerted by China's social credit system that assigns every citizen a score measuring their social and political trustworthiness and rewards or punishes them accordingly. While viewing that system as an attack on freedom and dignity, most, however, readily divulge their personal data to social media, not noticing that they are relinquishing control of intimate information in exchange for free services. Imagine a coffeehouse that offers free coffee. While you enjoy many hours there chatting with your friends, bugs and cameras wired into the tables and walls closely monitor your contacts and conversations. The room is also filled with salespeople who pay for your coffee and constantly interrupt you to offer their personalised products and services on sale. Social media would function in a healthier way if they were based on the business model of a real coffeehouse, where you as the customer pay for the amenities you want. Smart technology is an asset, but needs to be controlled by smart users. ◘

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