Workforce growth
Medical physics worldwide

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Let’s sit down to talk

>>> Conference and awards night
A highly successful event

MEDICAL PHYSICS
A special focus on proton therapy ahead of its arrival in UK clinics

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Word trending to identify patterns in free-text fields in reports

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Proton radiotherapy services

Usman I. Lula (Editor-In-Chief) introduces a special focus theme on the subject of high-energy proton radiotherapy services, due to be introduced in the UK this year.

Our main feature in this issue has kindly been supplied by Professor Slavik Tabakov, the current IOMP President. He talks about the growth of the medical physics workforce worldwide and the positive impact of the official International Labour Organization (ILO) recognition of medical physicists and biomedical engineers to the workforce in developing countries. IPEM and AAPM serve to provide educational models to medical physics societies worldwide and in this respect, educational training in developing countries is an important area of focus.

The UK is undergoing an unprecedented change in radiotherapy with the introduction of high-energy proton radiotherapy services this year. In this issue, we have a special focus theme on proton radiotherapy with submissions from the public sector on some of the developments within the NHS, thanks to Professor Ranald Mackay (Christie NHS, Manchester) and Dr Matthew Aldridge (UCLH NHS, London). We also have a submission from the private sector on the development of their proton therapy service, thanks to Ramsay Smith (Media House) and Professor Karol Sikora (Proton Partners International). The theme wouldn’t have been complete without articles on the radiobiology of protons and a series on proton dosimetry, thanks to Professor Bleddyn Jones (Oxford University) and Russell Thomas (NPL, London), respectively. Dr Paul Doolan kicks off with an introduction to the theme and Professor Stuart Green (QEH, Birmingham) provides an insight to the potential future developments in radiotherapy (see below).

Are you looking to plan your career in medical physics or clinical/biomedical engineering? We have an excellent instalment from our past Scope Editor, Dr Chris Daniel, who looks at his own career and raises important questions around career planning with a strategy on how to plan your own. A must read!

Amongst other interesting articles in this issue, Dr Ellen Donovan writes her fourth article in the fascinating series of clinical academic research, focusing on the interview process and associated preparation. We have our usual submissions – policy update by Sean Edmunds, question and answers panel by Mark McDade and a series of special reports by Kirsten Hughes.

Are you a technologist or a student working towards the PTP, STP, Route 2 or HSST working on anything that would interest the Scope readership? Are you planning to retire soon, have recently retired or are working at a senior level in medical physics or clinical and biomedical engineering and would like to share your experiences? If so, I would be interested to hear from you about your ideas and thoughts for Scope.

Enjoy!

Usman I. Lula
Editor-in-Chief

Email any comments to Usman.Lula@uhb.nhs.uk

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Treatment of NHS patients with high-energy proton radiotherapy will begin this year at The Christie Hospital, to be followed in a few years by University College London Hospital. These centres will help bring the portfolio of treatments available in the UK to NHS patients up to a basic standard of international acceptability. The clinical indications will be highly selected initially but, through trials, evidence will be gathered for new indications.

The high-energy proton programme contributes greatly to the development of NHS radiotherapy capability. It extends recent progress in x-ray radiotherapy which has seen our beam delivery advance from conformal to volumetric intensity-modulated, often now with volumetric delivery. These developments come together in new capabilities such as SABR. The pace of development in recent years has been rapid, but there is no time to pause as this pace is unlikely to slow.

In the future, there will be technical developments related to the dose delivery with the use of more sophisticated adaptive radiotherapy including image guidance via MRI. Delivery of light ions has the potential to bring benefits in selected cases and is being actively evaluated in Europe and Asia, and there is potential to deliver ions in novel ways with binary techniques such as boron neutron capture therapy (BNCT). However, there are other developments which are likely to dramatically change our practice, with initial efforts already entering trials.

In the future, radiotherapy beam delivery is very likely to be:

- Combined with agents that have the capability to enhance the local dose, and the local effect of the dose. Depending on the magnitude of the effects achieved, these agents could allow reduction of both total dose and number of fractions and bring the potential to reduce treatment-related toxicity to new lows.
- Combined with agents that have the capability to use the induced radiation damage to trigger the immune system and generate a systemic response to the cancer. These could make contributions to overall cure rates which are currently unachievable and, until very recently, impossible to envisage.

Many of these developments are biological in nature and it may appear that they are outside the realm of physics and physicists. However, this is not the whole picture. Where new approaches are biological, modelling (a key strength of the physics community) will be key to their optimisation and evaluation. However, as recent publications on ultrasound-activated oxygen-loaded microbubbles show, physical techniques also have a role in enhancing the biological effect of radiation. In a similar vein, techniques such as BNCT and other nanoparticle ‘contrast’ agents are intended to enhance both local dose and biological effect.

Advances in radiotherapy will continue to come in a step-by-step and site-by-site way. NHS centres began to move substantially into IMRT perhaps 10–12 years ago. Those 10–12 years have seen dramatic change and the proton centres are an important milestone in that development. However, the next 10–12 years could see a revolution in the way that radiotherapy is practiced. It could be quite a ride…
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FEEDBACK
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Welcome to the March 2018 issue of Scope. I am proud to be the Vice President (VP) External of IPEM, which means that I sit on the IPEM Trustee Board and chair the IPEM Communications Committee. As VP External, I have an overview of the way that IPEM is perceived by the membership, other professional bodies and the general public, whilst supporting the President in his/her role. The Communications Committee is in place to develop and oversee the implementation of the IPEM Communications and External Relations Strategy and to provide a focal point for internal and external communications.

Outside of my voluntary IPEM role, I am a Clinical Scientist in the Radiation Protection Group at University Hospital Southampton NHS Foundation Trust, having recently moved from Barts Health NHS Trust.

IPEM’s 150 Women in Medical Physics campaign
In this issue of Scope you will find an article by Eva McClean, IPEM Communications and Development Manager, discussing the ‘150 Women in Medical Physics’ campaign for the International Day of Medical Physics 2017. To celebrate Marie Curie’s 150th birthday, IPEM collated photographs of 150 female medical physicists from around the world into an eye-catching poster. It can still be downloaded from the IPEM website should any members wish to add it to their outreach or public engagement materials. When we first discussed the campaign at a Communications Committee meeting, I thought that I’d set us an insurmountable task and that we’d never get 150 submissions. However, it seemed far more achievable and environmentally friendly than some of the other ideas that I’d come up with (for example, launching 150 IPEM balloons off the top of the Royal London Hospital) and I was determined to avoid baking at all costs.

I would like to say a big thank you to everyone who submitted their photograph for our campaign. This campaign was so much more than just a poster. We had submissions from every continent on the planet, with some of our contributors going on to become new IPEM members. I still can’t believe that we crashed through the 150 barrier and had to turn people away towards the end of the campaign. I love the fact that the poster is full of happy, smiling women at all different stages of their career and all from different backgrounds. It’s amazing how many faces you recognise but also how many faces you do not recognise, which just goes to show that the community is bigger than we might realise and that you absolutely cannot stick a ‘female scientist’ into a stereotypical box. I encourage any of our female members who are eligible for IPEM Fellowship to apply, as only 10 per cent of IPEM Fellows are women.

Furthermore, this campaign was so much more than just a poster because it has been used at countless outreach and public engagement events all over the world to inspire the next generation. The IPEM values statement says that we aspire to be ‘an organisation that inspires passion in others to promote science and engineering in medicine for public benefit’, and I believe that this campaign embraced this. I feel strongly about showcasing our career as an open and welcoming choice for all, irrespective of gender, age, religion, ethnicity or sexual orientation. IPEM has recently shared the results of an Equality, Diversity and Inclusivity (EDI) survey of the membership. The purpose of this survey is to enable IPEM to support all of our members and to enable us to benchmark our progress in EDI. IPEM has made huge leaps in this area in recent years and this must continue. As a profession we are critically low in skilled scientists and rule out an entire group of talented young people. More information about our EDI work can be found on the IPEM website.

Getting involved with IPEM
Finally, I would like to encourage anyone and everyone to get involved with IPEM as little or as much as they are able to. There are so many opportunities from outreach to scientific committees and beyond. Remember, you always get more out than you put in. Please get in touch if you have any ideas for IPEM or if you would like to discuss any of the topics I have mentioned. I look forward to hearing from you.

150 WOMEN IN MEDICAL PHYSICS POSTER
You can download the poster from the IPEM website: http://bit.ly/2DBbLW7

Email any comments on this article to Fiona.Wall@uhs.nhs.uk
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I'm tremendously impressed with all of the academics who are delivering the course, the quality of teaching, and the quality of their research that so clearly underpins it, as well as the structure and delivery mode of the materials.

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Find out more online: bit.ly/2BNfqCv
International celebrations

Eva McClean (Communications and Development Manager) celebrated women to mark the International Day of Medical Physics and the 150th birthday of Marie Curie.

The International Day of Medical Physics (7th November) was initiated by the International Organization for Medical Physics (IOMP) and is now in its fifth year. The date was initially chosen as it is the birthday of Marie Curie and links to her pioneering work on radioactivity.

Every year the day has a theme, and in 2017 the official theme recognised the fact that it would have been the 150th birthday of Marie Curie, and therefore focused on women in medical physics. The official title was: ‘Medical Physics: Providing a Holistic Approach to Women Patients and Women Staff Safety in Radiation Medicine’.

We wanted to mark the day and engage with our female members and international contacts. During a Communications Committee meeting the idea was developed to collect photos from 150 women and create a poster to celebrate the day.

Watch out for the 2018 International Day of Medical Physics which will be based on our 2016 campaign – Science for Patient Benefit!

The result was overwhelming – women from across the world got involved and asked to be featured on the poster. Social media played a big role in promoting this and many women responded to our Twitter campaign. Our contacts from EFOMP (European Federation of Organisations for Medical Physics) and IOMP also supported the campaign and contacted their members and networks.

In the end, many more than 150 women from every continent responded to the call, from Canada to Australia, Chile to India, and all points inbetween.

Fiona Wall, Chair of the Communications Committee and IPEM’s Vice President External, who initiated the idea, said: ‘I am absolutely delighted that so many women right around the world responded to our call’.

The photos we received were then sent to a designer who created this wonderfully striking poster. We put designs in different formats onto our website and encouraged everyone to download the files, to either print them locally or display them electronically. We also had some ready-made Tweets for people to share and succeeded in reaching our numbers for a ‘Thunderclap’. This is a social media activity whereby participants sign up in advance and all of their Tweets and Facebook posts are released at the same time to maximise impact.

What happened on the day

In the UK, our members held a number of events such as a scientific conference in Newcastle upon Tyne, a school outreach event in Birmingham and hospital events in Southampton, Nottingham, Romford and London.

Internationally, IOMP staged a number of global online events which were live streamed on the day in Kuala Lumpur, Jaipur and Vienna, some of which can still be viewed online. Many other countries held national events and promoted the day.

Email any comments to eva@ipem.ac.uk

#IDMP2017 in numbers, proudly showing our success with the event.

- 120,391 – The number of Twitter impressions for the duration of the campaign (the number of people who were potentially reached as our followers Retweeted with our Tweets), an increase of 726% for this period
- 2,228 – The number of active Twitter engagements for the week of IDMP (these are Retweets, likes and clicks)
- 2,355 – The number of people who visited our Twitter profile (i.e. looked at our Twitter ‘homepage’)
- 45 – The number of people trying to encourage Professor Brian Cox to Retweet our poster image (sadly he didn’t…)
- 2,856 – the number of visitors to our IDMP webpage since the posters were uploaded

Scope welcomes your feedback! #IPEMScope, @IPEMScope
IPEM’s officers and committee members work hard on behalf of the Institute trying to influence policy at all levels, around the UK and in the wider world, to achieve IPEM’s strategic objectives. Some of their efforts are listed below, but for a fuller picture keep an eye on the policy pages of the website, under News and External Affairs.


Dr Jemimah Eve, IPEM’s Workforce Intelligence Unit Manager, attended a meeting for members of the Campaign for Science and Engineering (CaSE), of which IPEM is a member. The meeting was held to share insight and identify shared messages and goals for the Brexit negotiations. The meeting was followed by a conversation with UK Research and Innovation (UKRI) Chief Executive Officer designate, Sir Mark Walport. Sir Mark is keen to engage with leaders of CaSE member organisations on the role of UKRI in securing positive outcomes for science over the next few years.

IPEM’s Radiation Protection Expert (RPE)/Medical Physics Expert (MPE) task group produced guidance on completing the Department of Health MPE recognition scheme, together with a number of frequently asked questions and answers to help members comply with the requirements of applying to be recognised as an IR(ME)R 2000 Medical Physics Expert.

IPEM was closely involved with the consultation and feedback processes during the period leading up to the implementation of the revision of Ionising Radiation Regulations 2017 and the Ionising Radiation (Medical Exposure) Regulations 2018.

**Responses to Regulations**

The Institute led on producing a collaborative response to the IRR 2017 consultation representing medical sector views, together with the Royal College of Radiologists, the British Institute of Radiology and the Society of Radiographers. IPEM also submitted its own response to the IR(MEI)R 2018 consultation. Several of IPEM’s Special Interest Groups, together with other Institute members, were closely involved in producing these responses.

IPEM also hosted a meeting with lead inspectors and policy managers from the Health and Safety Executive. Radiation Protection Advisers and experts from across ionising radiation medical physics presented medical sector views on IRR 2017 and the associated Approved Code of Practice (ACoP). A letter from the then IPEM President, Professor David Brettle, was sent to the HSE Chief Executive emphasising a number of important points for consideration, including the financial and operational implications for the medical sector of including a broadly applicable instantaneous dose-rate constraint of 7.5 μSv/hr in the ACoP.

IPEM has sent a joint proposal, together with the Association of University Radiation Protection Officers and the Society for Radiological Protection, for certification of MPEs and RPEs (including Radiation Protection Advisers and Radioactive Waste Advisers) to the radiation regulators. The document covers proposals on the format of the registering and assessing bodies, the processes for initial and continuing recognition as an MPE or RPE and the principles of common competence across MPE and RPE recognition schemes.

Written evidence was submitted to the House of Commons Health Select Committee inquiry on ‘Brexit: Medicines, Medical Devices and Substances of Human Origin’, with invaluable input being provided by IPEM Fellow Justin McCarthy. The inquiry was launched to look at the regulatory arrangements needed to guarantee the safe and effective supply of medicines, medical devices and products post Brexit.

The Department for Business, Energy & Industrial Strategy launched two separate consultations. One concerned radiological protection and emergency preparedness and the other was looking into the revised requirements for radiological protection with regards to the regulation of public exposures and the justification of practices.

**New consultations**

The Department of Health for Northern Ireland also launched two inquiries, one of which concerned the strategic framework for imaging services, which members of IPEM’s Diagnostic Radiology, Magnetic Resonance and Ultrasound and Non-Ionising Radiation SIGs provided input on. The second consultation concerned the introduction of new regulations – the Ionising Radiation (Medical Exposure) Regulations (Northern Ireland) 2018 to replace the IR(ME)R 2000 regulations.

NHS England launched a consultation on modernising radiotherapy services, this time looking at the proposed service specification for adult services, as opposed to the much wider consultation on future service models which was held in the last year.

Finally, the Department of Health launched a consultation on promoting professionalism, reforming regulation, to seek views on the reforms needed to help maximise public protection whilst supporting workforce development. This wide-ranging consultation had implications for the registration of Clinical Scientists and other groups of professionals.
MEDICAL PHYSICISTS ARE now an intrinsic part of contemporary medicine. The professional occupation ‘medical physicist’ was included 5 years ago in the latest version of the International Standard Classification of Occupations (ISCO-08), published by the International Labour Organization (ILO).1 In this very important document (used as a model in all countries developing/revising their national occupational classifications), medical physicists are among a few professional occupations listed in two main categories: in the sub-major group ‘Science and engineering professionals’ (Unit 2111 – our unique number), as well as in a footnote of the sub-major group ‘Health professionals’. Similarly, biomedical engineers made their debut in the ISCO listing under Unit 2149. This huge achievement of the International Union for Physical and Engineering Sciences in Medicine (IUPESM), the International Organization for Medical Physics (IOMP) and the International Federation of Medical and Biological Engineering (IFMBE) was of great importance for thousands of colleagues from low- and middle-income (LMI) countries who were suffering from a lack of recognition and the inability to be employed as medical physicists.

This recent recognition will be very useful for the future, in reducing the unequal global distribution of the workforce as seen in the current IOMP data. From the c.25,000 medical physicists in the world (in 86 national societies, data from 2016), more than 70 per cent are in North America and Europe, whilst the rest are distributed in the other continents.2 This way, the number of medical physicists per million of the population is c.23.8 in North America, c.11.4 in Europe (although unequally distributed) and less than 2 per million in the rest of the world (table 1).

This data is based only on medical physicists who are listed in their national societies, but even if we include those who are not members of societies, or who are working in the industry and other institutions, we still end up with a very small number of medical physicists per million of the population. This significantly affects the provision of healthcare in radiotherapy and medical imaging in these regions/continents.

The situation needs urgent attention if we take into account the recently published report Global Task Force on Radiotherapy for Cancer Control.7 This very important document estimates that by 2035, just for the area of radiotherapy, the need for newly trained medical physicists will be of the order of 17,200 (for high-income countries), 12,500 (for upper-middle-income countries), 7,200 (for lower-middle-income countries) and 2,400 (for low-income countries). Added to this, the need for medical physicists contributing to medical imaging and radiation safety will result in approximately tripling the global number of medical physicists in the next two decades (2015–25 and 2025–35). This enormous global challenge for the profession (and for healthcare as a whole) was recently presented at the WHO Fourth Global Forum on Human Resources for Health. Whilst large international organisations (such as WHO and IAEA) will continue to play important roles in dealing with this challenge, we, as professionals have to take early steps in this direction.

Looking at the development of the medical physics workforce in the past 50 years we can find lessons on how to address this challenge.

As per the IOMP data around 1965 there were c.6,000 medical physicists in the world. IOMP was established in the UK during 1963 with 4 National member societies - UK, USA, Canada and Sweden [4]. Outside this statistics would be the small number of professionals in countries where medical physics societies had not yet been formed (or were formed recently but not yet joined the IOMP).

Further, IOMP data shows that during the first decade of the organisation (1965–75), the global number of medical physicists (members of national societies) increased to about 8,000. In the next decade (1975–85), the global number of medical physicists increased to about 10,000. The growth of approximately 2,000 professionals per decade also continued in the next period (1985–95), when the global number of medical physicists increased to about 12,000. This way, about 30 years after the formation of IOMP the global number of professional medical physicists reached 25,000.

**TABLE 1. Approximate data on the number of medical physicists in the main regions of LMI countries**

<table>
<thead>
<tr>
<th>Region</th>
<th>Approximate number of medical physicists</th>
<th>Per million of the population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latin America</td>
<td>c.800</td>
<td>1.25</td>
</tr>
<tr>
<td>Middle East</td>
<td>c.600</td>
<td>1.61</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>c.500</td>
<td>0.78</td>
</tr>
<tr>
<td>The rest of Asia</td>
<td>c.4,600</td>
<td>1.33</td>
</tr>
<tr>
<td>Africa</td>
<td>c.400</td>
<td>0.33</td>
</tr>
</tbody>
</table>

The number of medical physicists globally, of which 70 per cent are in North America and Europe alone.
medical physicists had doubled. The period 1995–2005 was marked with double growth per decade (from 2,000 to 4,000) and by 2005 the global number of medical physicists reached about 16,000. This period is distinctive with extensive development of medical physics education and training. Many countries established new MSc (or related) university courses. For example, after the International Conference in Medical Radiation Physics Postgraduate Education (Budapest, 1994), almost all countries from Eastern Europe developed their own medical physics education courses. This period was also notable for the introduction of e-learning in medical physics and the opening of a number of internet-based educational activities.6

![Figure 1. Growth in the global number of medical physicists (per decade) in the period 1965–2015](image1.png)

The strong emphasis on education and training continued into the next decade (2005–15) when the global growth of medical physicists was the largest so far – an increase of around 8,000 per decade in what was again double growth compared with the previous decade. This way, about 50 years after the establishment of IOMP, the global number of medical physicists had quadrupled (figure 1).

![Figure 2. Visits per day to the EMITEL e-Encyclopaedia website](image2.png)

During the 2005–15 decade, e-learning in medical physics developed very strongly and the free availability of teaching materials on the Internet supported many colleagues from LMI countries. As an example, during September 2017 alone, visits to the website of the e-learning materials EMERALD and EMIT were 4,500, whilst visits to the e-Encyclopaedia EMITEL website were c.10,500 (figure 2).

IOMP firmly supports the expansion of educational activities. During 2016, it launched a new activity called ‘IOMP School’, which was made available for free to all colleagues in LMI countries (at ICMP2016, Bangkok, and at AOCP2017, Jaipur). A new IOMP School is now planned for the WC2018 in Prague. Additionally, the interest in educational and professional issues is illustrated by the increased number of visits to the IOMP free online Journal Medical Physics International (www.mpijournal.org). During September 2017, these were c.13,800 (again c.60 per cent from LMI countries).

Another strong example of the need for an increased focus on education and training is the fact that the largest groups of medical physicists are in the UK and USA, where the education and training activities are the most advanced (the IPEM and AAPM practices are often used as examples by other medical physics societies). AAPM and IOMP collaborate very successfully through the International Library Programme and the International Affairs Committee activities. Around half of all the international educational activities are based on this collaboration. Additionally, AAPM offered free access to its excellent Virtual Library for all LMI countries. IPEM expertise will be welcome in similar collaborations aiming to support our colleagues from LMI countries.

A strong focus on education/training activities and international collaboration on the subject will be the main drive for achieving the expected triple growth of the profession by 2035.

**REFERENCES**


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**IOMP PRESIDENT**

**PROFESSOR SLAVIK TABAKOV**

Slavik has made significant contributions to the development and dissemination of medical physics education and has pioneered e-learning in the profession.

Email any comments on this article to slavik.tabakov@kcl.ac.uk

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**> AFFILIATION**

Slavik Tabakov is Consultant and Reader in Medical Physics at King’s College London.
Can you write an article for Scope?

Please contact the Editor, Usman Lula
E. Usman.Lula@uhb.nhs.uk

I am sure you agree that Scope is a high-quality publication for IPEM members to read. We seek to make it relevant and important reading material for people working in the field, as well as anyone with an interest in medical physics and clinical & bioengineering. To ensure that Scope is filled with interesting, informative and valuable material, we rely entirely on you to submit articles.

Scope is published four times a year and includes a varied number of feature articles. This is only possible if you continue to provide us with great material. The readership survey revealed that a number of people were willing to write articles. If you were one of the people who expressed interest in doing so (or even if you weren't!), please give it serious consideration. Perhaps you have an idea that could be turned into a feature article but do not feel you are the right person to write it? Ask a friend! Alternatively, simply let us know about your idea and we will try to take it forward.

The submission process is simple and articles are normally published in the next issue. It will also count towards your CPD.
Dr Chris Daniel (Head of Rehabilitation Engineering) wonders what has happened to his 30-year NHS career so he sets out to find it and have a talk with it.
However, it continued, ‘you obviously can’t be expected to know exactly where you will be in 5 year’s or even 2 year’s time – in practice your choices will largely be limited by the availability of suitable jobs and by your personal circumstances, but you need to set a direction for yourself. Career progression can involve moving from one organisation to another or it could take place in the same organisation as you gain experience and take on more responsibility. In any event, careers usually only progress one step at a time.’

‘Well, I certainly only moved one job at a time. However, I’m still not sure if I had a plan. I think my first 5 or even 10 years were more of a random walk in science.’

‘Remind me about it’, said my career, settling back into its chair, fingertips pressed together.

‘Well, I enjoyed science at school, so I did a physics degree, which led to a Masters and then a PhD.’ ‘So far so good’, said my career. ‘That wasn’t a random walk – you were making intentional decisions when opportunities came up.’ ‘OK’, I said, ‘but that was just my academic career. What about my “real” career?’ My career looked at me oddly. ‘All of me is real’, it said. ‘A career is not just your employment or your education, it’s to do with learning about yourself too – in other words, developing the whole of you.

‘So carry on, tell me what happened after you finished at university.’

‘My first job followed logically from my PhD project, but after a couple of years I realised that I wasn’t happy there, so I started looking for a different type of job in which I could use my skills. Eventually I found it; ‘Well there you are’, said my career, sitting up. ‘You demonstrated the first two of Stephen Covey’s 7 Habits of Highly Effective People: you were proactive in seeking change and you began with the end in mind; in other words, you knew what you were looking for. That was enough to get you onto the main path of your working life.’

‘That’s good to know’, I said. ‘Things went well for a long time but after about 10 years I realised that I was growing out of the job and that if I didn’t look for the next step then I could be stuck there for the rest of my life.’

‘That’s right’, said my career. ‘That’s when you really brought me into your considerations. You had asked a senior colleague to be your mentor and you reflected with him on your feelings of dissatisfaction with the job, which made you realise that you had to move on. By that time you had built up a network of contacts and that had a part to play in you being selected for your next job.

‘If a “career” is a series of connected employment opportunities then your next job satisfied that definition – it was in a similar field but with more responsibility and built on the experience you had gained to date. The new job felt right to you and empowered you. Your life was back in balance.’ ‘That sounds quite grand’, I said, ‘but I guess that sums it up’.

‘But’, I continued, ‘that brings me back to the present because it’s pretty much where I’ve been since then. Does that mean my career has stopped?’

‘Of course not, as long as you can answer the following questions honestly:

- Are you happy in your job? Does it give you a sense of value, identity and purpose?
- Are there still challenges in your job that you want to take on and things you still want to achieve?
- Do you have the vision to improve and develop your job role? And do you have the freedom to do it?
- Do you have the opportunity to learn more through self study or training courses?

‘If you answer “yes” to most of these questions then you are probably in the right job for now. If, however, you feel you’ve been in your job for too long, are no longer interested in the work, feel undervalued and are making no progress, then it may be time to consider a change.’

‘Well’, I smiled, ‘I think I know which of those two situations applies to me.’

I thanked my career for this encouraging consultation as I shook it warmly by the hand. ‘Remember’, it said, ‘I’m always here to help you stay on track. Come and see me again.’ As I turned to go, it added with a smile, ‘Oh, and try not to leave it so long next time.’

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## CAREER PLANNING – A SUMMARY

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<tr>
<td>1</td>
<td>Develop a career plan – decide on your career goals and the direction you want to take, incorporating your interests, skills, personal circumstances and values</td>
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<td>2</td>
<td>Share your plan with a colleague – your manager or mentor</td>
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<td>3</td>
<td>Find out what training you need and take every opportunity that your organisation offers to advance your career</td>
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<tr>
<td>4</td>
<td>Review your plan regularly – at least annually</td>
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**HEAD OF REHABILITATION ENGINEERING DR CHRIS DANIEL**

Chris is an assessor for Parts I and II and STP trainees. He was also a past Editor of Scope and secretary of the Rehabilitation and Biomechanics Special Interest Group

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Email any comments on this article to Chris.Daniel@wales.nhs.uk

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### REFERENCE

Conference and awards night

Last year, the first joint MEI-Bioeng/MPEC conference was held at Sandown Park Racecourse. Sean Edmunds (IPEM’s External Relations Manager) summarises what turned out to be a highly successful conference.

The first joint MEI-Bioeng/MPEC conference, bringing together the academic biomedical engineering community and physicists and engineers working in healthcare, was a huge success and featured a wealth of high-profile speakers – and the inauguration of a new IPEM President.

Held over two days in September 2017 at Sandown Park Racecourse just outside London, almost 250 people attended the multidisciplinary conference.

Opened by outgoing IPEM President Professor David Bettle and Professor Reza Razavi, the Vice President and Vice Principal (Research) at King’s College London, the conference featured a wealth of great speakers and a varied programme of talks, lectures and workshops.

Developments across Europe

The Woolmer Lecture, in particular, given by Professor Josef Käs, Head of Soft Matter Physics at the University of Leipzig, caught the audience’s attention with his new theory on why cervical cancer cells spread to some organs in preference to others.

Fresh from their council and board meeting in York, delegates from the European Federation of Organisations for Medical Physics gave an update and insight into developments across Europe, including education and training initiatives and a report on the European Examination Board, which introduces the European Diploma of Medical Physics (EDMP) and the European Attestation Certificate to those medical physicists who have reached the Medical Physics Expert level (EACMPE).

Varied subjects of discussion

IPEM’s latest Honorary Fellow, Professor Marco Viceconti, Executive Director of the Insigneo Institute at the University of Sheffield, gave the plenary lecture on ‘Subject-specific modelling in healthcare: now’s the time’.

The Royal Academy of Engineering hosted a panel discussion, led by Dr Alan Walker, Head of Policy at the Academy, on ‘Influencing decision-makers: a researcher’s guide’. The panel featured Dr Helen Meese, Head of Healthcare for the Institution of Mechanical Engineers; Dr Helen Bodmer, Department of Business, Energy & Industrial Strategy; Nishran Sunthares, Chief Operating Officer for the Association of British Healthcare Industries, and Graeme Tunbridge, Group Manager for Device Regulatory Affairs at the Medicines and Healthcare Products Regulatory Agency.
Trainees and students gave a variety of talks, including one by Areeb Zar of King’s College London on presurgical planning for robot-assisted transoesophageal echocardiography, a technique used in cardiac procedures.

The Chair of IPEM’s Fellowship Panel, Dr Stephen O’Connor, spent time inbetween sessions talking to more than half a dozen Full Members who were considering applying to become Fellows of the Institute.

**The awards ceremony**

At the IPEM Annual General Meeting, held during the conference, the IPEM Presidency changed hands, with Professor David Brettle handing over the chain of office to Professor Mark Tooley. Professor Tooley subsequently presented the awards and prizes during a reception and awards ceremony to recipients who were at the conference.

As well as the Gold Medal winners (who were featured in December’s issue of Scope), a number of other awards were presented on the night.

The Roy Ellis Patient Benefit Award was presented to Dr Jonathan Ashmore and Dr Cormac McGrath for the interactive app they have developed to prepare children for MRI scans by creating a 360° virtual reality video of the entire MRI journey, from arriving at the department to undergoing the scan itself.

The Martin Black Prize for the best paper in IPEM’s international journal *Physiological Measurement*, published by IOP Publishing, was collected by Dr Peter Charlton on behalf of his colleagues for their paper entitled ‘An assessment of algorithms to estimate respiratory rate from the electrocardiogram and photoplethysmogram’.

The final award made on the night was IPEM’s highest award, of Honorary Fellowship, which was presented to Professor Viceconti.

Elsewhere at the conference, the Royal Society held a workshop on ‘Research culture: visions of 2035’ and a packed industry session featured, amongst others, talks by Stefan Wijnen of Microsoft Research and Dr Christopher Austin of GE Healthcare.

**In summary**

Professor Stephen Keevil, Scientific Programme Committee Chair of the conference from King’s College London, the host Medical Engineering Centre, said: ‘I am really pleased that we achieved mixed sessions with both clinical and academic presentations that complemented each other very well. In several sessions that I attended, people from quite different areas and backgrounds were bouncing ideas off each other. The virtual reality workshop was also a real success, with more than 40 people who really enjoyed the interactive approach’.

Rosemary Cook, IPEM’s Chief Executive, said: ‘I am delighted that this first-ever joint conference was such a success, with some fantastic speakers and an incredibly varied scientific programme. I would like to thank all of our keynote speakers and our partners, and congratulate all of our prize winners. I look forward to seeing everyone in York this September for MPEC 2018’.

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Email any comments on this article to sean@ipem.ac.uk
Questions to be answered by our experts

Our column today concerns the issue of consent in the nuclear medicine community, with an intriguing question from Anthony Cartwright.

From my interpretation, a referral for a medical therapeutic or diagnostic procedure of any kind involves a responsibility to communicate with the patient to obtain their consent. Having spoken to several clinicians, this seems to be something that is taught to trainee doctors, such that they bear the majority of responsibility.

In nuclear medicine, specific consent forms are often used to document the consent process for therapies, although are often not used for diagnostic procedures. However, I couldn’t find a discrepancy between therapeutic and diagnostic procedures in the Health and Social Care Act, but I did find a responsibility that relates to Regulation 13, where there may have been a problem in the consent-taking process and the patient has to be safeguarded.

A practical example is when a referral goes to the ARSAC certificate holder, who alters the referral to a different test having not met the patient. The patient may expect one thing and be sent for something else. My work used to involve screening patients and checking their identity, and practically you can assume that the patient has consented to the procedure by turning up for their appointment. However, there have been a few occasions where the patient found out a bit more information by asking questions and decided that they didn’t want the examination.

For example, a patient attends for a renogram, expecting no side effects from the diuretic or to have to do anything more than have two injections and lie down. The reality often includes side effects and may include imaging during micturition.

As far as I am aware under the current regulations, scientists, technologists or radiographers cannot take consent, leaving those duty holders in a difficult position.

Please correct me if I have misinterpreted the legislative framework. In terms of what can...
be done to prevent a consent-related incident, I’d appreciate an expert’s opinion.

Question supplied by Anthony Cartwright

‘My understanding is that there are different types of consent. The best way to describe this is to work through a scenario of a patient’s journey.

The first consent

A patient is with their clinician in a urology clinic and is informed that some tests will be needed. The clinician will ask the patient if they are happy to undergo some tests (verbal consent), and puts in a referral for a DMSA test stating the clinical question and adding the necessary clinical details into the referral, as any diligent referrer does. The clinician, as you describe, is consenting the patient for investigations into their health issue.

A change of procedure

On its receipt in the nuclear medicine clinic, the nuclear medicine practitioner reads the request and determines that the best test to answer the clinical question is a renogram with diuretic. It is the duty of the nuclear medicine practitioner to choose the appropriate test to answer the clinical question being asked. They may contact the referrer to explain their decision, but in practice this is often not necessary or practical.

The information dilemma

The patient is in a position where they are expecting one type of test (DMSA), but are on course for a different type of test (renogram). Either as part of the letter, or as a separate patient information sheet, the patient will also be informed about what will happen in the test, together with the effects of any drugs used, and whether, for example, the test will be in small spaces or requires the patient to stay still for a prolonged period of time. The patient is now informed about what to expect when they attend their investigation – a necessary part of informed consent.

Consent prior to the procedure

Consent has no validity unless it is informed. Although in law this procedure should be carried out by a medical practitioner, this duty can be delegated under protocol to an appropriately trained (and listed) radiographer, technologist or nurse.

Type of consent

The consent given by the patient does not hold extra validity if it is written, but a signature does provide evidence of consent. A verbal consent is still valid, and may be chosen in low-risk or non-invasive procedures for practical purposes. For therapeutic processes such as lithotripsy, or invasive processes such as urinary endoscopy, it is mostly always recorded as written consent given the nature of these procedures, but it is not strictly necessary – verbal consent would be adequate, although not often approved in hospital policies.’

Dr John Dickson, Chair of the Nuclear Medicine Special Interest Group

REFERENCES


Many thanks to Anthony for his question and of course to our expert. If you are seeking clarity on issues of registration, training, professional standards or just horizon scanning – you know what to do!

Dr John Dickson

Title: Medical Physicist

Working history: University College London Hospitals NHS Foundation Trust

Expertise: Chair of the Nuclear Medicine Special Interest Group

John has been involved in brain imaging both clinically and for research since he completed his PhD in neuroimaging, and has been involved in many UK and international research collaborations since.

◆ ASK THE EXPERTS

Our new ‘Ask the experts’ column engages questions and short letters from our member clinical technologists/scientists and engineers.

Here we will facilitate multidisciplinary interaction within the different arms of IPEM and the RCT. So get writing!

Send your submissions to mark.mcdade@nhs.net
Proton therapy

Dr Paul Doolan (German Oncology Center) introduces the special focus theme on proton therapy, ahead of its arrival at clinics in the UK

INTRODUCTION

The concept of treating cancer using high-energy beams of protons is not new. First conceived in 1946 by Robert Wilson, following a period in which patients were treated only in laboratory facilities, the first hospital-based high-energy facility opened in 1990 at Loma Linda University Medical Center (California, USA). As of December 2017, there are 66 proton centres in operation worldwide. This rapid expansion has been driven by the potential clinical advantages of proton beam therapy (PBT) over conventional photon radiotherapy (RT). Being positively charged particles with mass, protons lose energy as they traverse patient anatomy, slowing down and becoming more densely ionising as they approach their end of range, at which point they stop. This results in a distribution with a low entrance dose increasing to a maximum, the Bragg peak, beyond which no further dose is deposited. By comparison, photons continue depositing dose at depths beyond that of the target. The depth of the Bragg peak is determined by the initial energy of the proton beam, which is selected to deposit the maximum dose at the position of the target. A therapeutic dose can be realised with reduced dose to surrounding healthy tissue compared to RT, resulting in the potential for reduced acute and late toxicities, reduced secondary cancer risk and an improvement in the patient’s quality of life.

The NHS currently only has one low-energy (maximum penetration ~3 cm in water) PBT facility at Clatterbridge, which has been treating ocular tumours very successfully since 1986. The overwhelming clinical efficacy of PBT, coupled with falling construction costs, has been sufficiently compelling for the NHS to extend their provision to two new high-energy beams at University College London Hospital and The Christie. Both public and private proton treatment centres are expected to begin treatment this year and this Scope issue focuses on their progress.

Proton clinical radiobiology

Professor Bleddyn Jones (University of Oxford) explains how proton therapy contains radiobiological uncertainties within the prescription process, but should produce clinical outcome gains

RADIOThERAPY

Now is the time for medical physicists and clinicians to develop an interest in the associated scientific base and the latest clinical results of proton therapy. Apart from the complex issues surrounding placement and spread of Bragg peaks to form treatment volumes, it is also important to remember that the biological effects of protons may vary with dose per fraction and also differ according to the tissue being treated.

The longstanding controversy regarding the conversion of photon to proton dose by the relative biological effectiveness (RBE) must be understood. Currently, the prescribed proton dose includes an RBE of 1.1 regardless of tissue, tumour and dose fractionation. This policy is questionable since the experimental cellular and acute-reacting in vivo tissue RBE data sets used were inappropriate for late normal tissue effects (LNTE). Also, the simplistic linear (but not linear-quadratic) analysis methods, and the use of a constant factor to convert low kilovoltage reference radiations to megavoltage equivalents for all biosystems, are also questionable.

The RBE ratio numerator is the photon-based dose, which is highly dependent on dose per fraction (d) for LNTE, so RBE must vary with d in such tissues. Analysis of previous fast neutron radiobiology data shows such effects clearly and it should not be forgotten that fast neutrons ionise biological systems mostly by the formation of recoil protons. Thus, RBE values of up to 2 or more may occur in parts of proton beams. It is also of concern that experiments have shown that proton RBE values increase sharply with LET at much lower LET values than other ions, but to similar maximum values. Consequently, there should be no room for complacency about protons being a low LET radiation.

Modelling systems, including the clinically useful biological effective dose (BED) concept, have been developed to estimate proton RBEs for different dose and linear energy transfer (LET) values. The latter reflect the increasing ionisation density along each proton track and within Bragg peaks. LNTE, such as severe brain damage with $\alpha/\beta = 2$ Gy, show higher RBE values than 1.1 at low dose per fraction (1.2–2 Gy) for typical treatment-volume LET values, with further increases in RBE towards the end of range (table 1). In general, the RBE is inversely related to the tissue $\alpha/\beta$ ratio at low clinical doses.

Another issue is that some experimental RBE reductions with tissue depth appear to depend on the beam delivery method used, occurring only with...
scattered beams, not with scanned beams, suggesting that particle intertrack distances and changing radiation fluence may be important.

To reduce unexpected severe clinical toxicity, which can exceed 10 per cent following proton therapy in some reports, the use of more rational RBE allocations, using LET-dependent RBE estimations which change with dose and tumour/normal tissue radiobiological characteristics (their α/β values), have been proposed. There is also some concern that in high α/β ratio tumours (as in radiosensitive childhood tumours and lymphomas), the RBE values can be below 1.1, leading to their underdosage. Not only should tissue tolerances be adjusted to include variable RBE, but the weighting of dose from each Bragg peak should take such effects into account. A non-uniform dose distribution, as shown in figure 1, would be required in order to achieve a uniform biological effective dose (BED) across a target volume if the LET distribution and its linkage with LET is taken into account. Clinical safety and efficacy should then improve.

### TABLE 1

<table>
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<th>Dose (Gy)</th>
<th>LET = 1</th>
<th>LET = 1.25</th>
<th>LET = 1.5</th>
<th>LET = 1.75</th>
<th>LET = 2</th>
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<th>LET = 3</th>
<th>LET = 4</th>
<th>LET = 8</th>
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<tr>
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<td>1.14</td>
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</tr>
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<td>d = 2</td>
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<td>1.33</td>
<td>1.62</td>
<td>1.75</td>
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**REFERENCES**


**PROFESSOR OF CLINICAL RADIOTOLOGY**

**PROFESSOR BLEDDYN JONES**

Bleddyn’s work is building the case for cancer treatment using charged particles.

Email any comments on this article to Bleddyn.Jones@oncology.ox.ac.uk
As of December 2017, there are 77 particle therapy centres in operation around the world, with a further 64 beamlines under construction or in the planning stages.1 The majority of these facilities offer, or will offer, proton therapy, which has clear dosimetric benefits compared to photons. But are protons the best particle of choice? It has been argued that heavier ions can do everything that can be done with protons, but better.2 They provide superior dose distributions due to reduced lateral scattering, reduced range straggling and a lower entrance dose. Additionally, with a higher linear energy transfer (LET), leading to an increased relative biological effectiveness of the tumour kill for some indications, such as for hypoxic tumours. However, increased RBE is an issue for normal tissues as well as tumour cells, and nuclear fragmentation becomes a problem.

To investigate the situations in which ¹⁶O may provide a benefit over lighter ions, targets were created in a phantom at different depths within two treatment plans with a target at 82 mm depth. In a uniform RBE-weighted plan (figure 1(a)), the agreement between calculated and measured doses was 1.3 per cent at the entrance and 2.5 per cent in the target. For a uniform physical dose plan (figure 1(b)), the agreement was 1.5 per cent in the entrance and 3.3 per cent in the target. Lateral profiles in the uniform physical dose plan also agreed well (figure 1(c)). Additional validation included the measurement of cell survival for Chinese hamster ovary cells after irradiation, under normoxic (21 per cent pO₂) and anoxic (0 per cent pO₂) conditions. Both sets of measurements agreed within 5 per cent.

Section Editor’s Comments
The authors concluded that the choice of ¹⁶O over ¹²C or ⁴He may be justified for more hypoxic target regions (partial oxygen pressure of 0.15 per cent or lower) and relatively low doses (4 Gy or lower). Given that the doses used for fractionated therapy are in the region of 1–3 Gy, this result offers promise for the future of ¹⁶O therapy. However, it should be remembered that the work was conducted in idealised simulation conditions.

**REFERENCES**
1 http://ptcog.web.psi.ch
2 doi:10.1118/1.4798945
3 doi:10.1088/1361-6560/aa88a0

**Email any comments on this article to paul.paul.doolan@goc.com.cy**

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**Oxygen therapy offers potential for hypoxic tumours**

**Dr Paul Doolan** (German Oncology Center) looks at a study which wonders whether protons are the best choice of particles for treating hypoxic tumours.
FIGURE 2. Schematic representation of the geometry for entrance channel survival tests, with the normoxic region in light green, the target shown by the shaded area and the variably sized hypoxic region in light red.

FIGURE 3. Dependency of EC survival on the size of the central hypoxic region, for (a) a survival fraction of 6.5 per cent and a 0.5 per cent pO₂ hypoxic region and (b) a survival fraction of 30 per cent and a 0.5 per cent pO₂ hypoxic region. The thin lines of the same colour show the 95 per cent confidence intervals for each dependency.

PHOTOACOUSTIC IMAGING
A team of scientists from Jerusalem have devised a method to overcome the acoustic diffraction limit to improve the spatial resolution of photoacoustic imaging, by taking advantage of flow-induced variations in the photoacoustic signals.
(doi.org/10.1364/OPTICA.4.001397)

EFFECTS OF SPACEFLIGHT
MRI has been used to study the impact of microgravity on the brains of astronauts. Comparing two groups who had been in space for short (mean flight time = 13.6 days) or long (164.8 days) periods of time, it was found that those who spent longer in space experienced narrowing of the central sulcus, upwards shifting of the brain and narrowing of the CSF spaces at the vertex.
(doi.org/10.1056/NEJMoa1705129)

SYNTHETIC HYDROGELS
It has been shown that synthetic hydrogels can be used to repair injuries in the intestine. The hydrogels were used to create a 3D matrix upon which human intestinal organoid growth is supported.
(doi:10.1038/ncb3632)

IN-HUMAN MRI-LINAC DATA
Utrecht have performed the first patient treatments using Elekta’s Unity MRI-linac. Plans were created whilst the patient was on the treatment table by deformably registering the CT Hounsfield unit values to the online 1.5 T MRI images.
(doi.org/10.1088/1361-6560/aa9517)

GLOBAL ACCESS TO PROTON THERAPY
An American-Lebanese collaboration has compared the projected lifetime risk of radiation-induced cancer at specific anatomical sites and mortality in paediatric medulloblastoma patients receiving proton or photon therapy. The researchers estimate that more than 1000 lives could be saved annually with global access to proton therapy.
Preparing for proton therapy in the UK

Professor Ranald Mackay was instrumental in gaining the funding to bring this new therapy to The Christie so find out about how the centre is getting ready to start introducing the service of at least a year’s work. Since that date, the initial proposal has been worked up into a detailed plan of delivery with full costing for the project and delivery of the clinical service. We did not break ground on our clinical service until August 2015, which means that the proton project was purely a paper project for longer than breaking ground to delivering the first patient. You may wonder what takes so long, and I do wonder that myself, but for a project of the size detailed plans for both the project phase and the clinical phase are key. One of the key parts in the approval process for us was having a fully costed clinical service. There is a tendency to concentrate on the cost of the technology but actually this is only a small part in what needs to be considered. Full lifetime costs of the facility should include at least the following:

- the cost of the proton therapy technology and the associated servicing costs;
- the cost of the build to accommodate the technology and the associated space for all the related clinical services;
- the cost of a proton treatment planning system and specialised dosimetry equipment;
- other technology that is required for the wider service such as pretreatment imaging (the NHS centres will have dedicated CT and MR on the treatment floor);
- detailed breakdown of the costs for other related clinical services; for instance, the centre in Manchester requires a considerable anaesthetic service for the anticipated number of paediatric patients;
- the cost of a technology refresh over the 20-year life of the facility;
- staffing costs for the project and clinical service, and
- the power costs to run the service.

Costs can only be calculated if there is a detailed clinical model based on the number of treatment rooms, the length of the clinical day and the number of fractions to deliver.

One of the disconcerting things about this phase of the project is how few people are involved with the paper phase of the project and how much responsibility is placed on relatively few key individuals. It is important to do your homework, or perhaps overseas work is more appropriate as visiting established centres is key. One of my observations is that many projects underestimate the time it takes to develop proton therapy, underrate the cost of proton therapy and overestimate the number of patients they can treat. It is too early to say that we have got all of this right but so far we are on time and on budget!

The Christie is due to open the UK’s first high-energy proton therapy NHS service in August 2018. I have been lucky enough to be involved from the start of this project and very much look forward to treating the first patients this year. This article outlines how The Christie, in particular the physics service, is preparing for proton therapy.

NHS proton therapy service
The NHS proton service is going to be a national service delivered from The Christie and UCLH in London. The Christie will go live this year. Currently, patients who require proton therapy go abroad, the majority to the US, but when the NHS service commences we will be able to treat those patients in the UK. This will lower the cost of treatment but also be much more convenient for patients. Many of the current treatments are for paediatric patients and involve the logistics of sending a family with a very ill young child overseas for 7 weeks of complex care.

The plan
The initial plan for proton therapy at The Christie was submitted to NHS England in March 2010, and that was the accumulation of at least a year’s work. Since that date, the initial proposal has been worked up into a detailed plan of delivery with full costing for the project and delivery of the clinical service. We did not break ground on our clinical service until August 2015, which means that the proton project was purely a paper project for longer than breaking ground to delivering the first patient. You may wonder what takes so long, and I do wonder that myself, but for a project of this size detailed plans for both the project phase and the clinical phase are key. One of the key parts in the approval process for us was having a fully costed clinical service. There is a tendency to concentrate on the cost of the technology but actually this is only a small part in what needs to be considered. Full lifetime costs of the facility should include at least the following:

- the cost of the proton therapy technology and the associated servicing costs;
- the cost of the build to accommodate the technology and the associated space for all the related clinical services;
- the cost of a proton treatment planning system and specialised dosimetry equipment;
- other technology that is required for the wider service such as pretreatment imaging (the NHS centres will have dedicated CT and MR on the treatment floor);
- detailed breakdown of the costs for other related clinical services; for instance, the centre in Manchester requires a considerable anaesthetic service for the anticipated number of paediatric patients;
- the cost of a technology refresh over the 20-year life of the facility;
- staffing costs for the project and clinical service, and
- the power costs to run the service.

Costs can only be calculated if there is a detailed clinical model based on the number of treatment rooms, the length of the clinical day and the number of fractions to deliver.

One of the disconcerting things about this phase of the project is how few people are involved with the paper phase of the project and how much responsibility is placed on relatively few key individuals. It is important to do your homework, or perhaps overseas work is more appropriate as visiting established centres is key. One of my observations is that many projects underestimate the time it takes to develop proton therapy, underrate the cost of proton therapy and overestimate the number of patients they can treat. It is too early to say that we have got all of this right but so far we are on time and on budget!
The gantry in place

**Procurement**

The phrase ‘Act in haste and repent at leisure’ should apply to tattoos and proton therapy equipment. The choice of manufacturer for proton therapy is diverse compared to the radiotherapy market. Further complications stem from the pace of change of technology and the considerable capital involved. There are several instances of projects that have stalled due to legal challenges on procurement.

Given these considerations, we added a further complication of a joint procurement for The Christie and UCLH. This made the procurement the largest radiotherapy tender in Europe. Fortunately, the Trusts managed to agree on the crucial technology aspects that could be used for full rotation gantries, spot scanning delivery and imaging in the treatment position. The competitive dialogue process took 12 months with the manufacturers responding to the demands of the tender, but also the requirements from the build teams who had to simultaneously arrive at a cost for the build. Eventually, Varian was chosen to supply both of the NHS centres.

**The build**

I think in general your average radiotherapy professional does not wish to get over-involved in build projects. Proton therapy generally involves a detailed build programme that has to interface with highly complex equipment. This means that there are at least three different organisations involved; the hospital, the equipment manufacturer and the build team. The key point is to be clear on responsibilities. There is an enormous amount of detailed information that needs to go between the build team and the equipment manufacturer. This needs careful management and version control. In our programme, both the build team and the manufacturer have contracts with the Trust, rather than with each other, and so you may find a lot of time is spent interfacing between the two. Take time in setting up the project to ensure that the framework will work for the hospital and make sure that responsibilities around issues such as radiation protection are well understood. In general, think twice and pour concrete once!

**Education and training**

Proton therapy is subtly different from conventional radiotherapy, and during the preparation one area of particular concern was how to recruit and train the appropriate workforce. On my first trip to an overseas centre they proudly boasted that in their centre they had employed staff from all the other operational centres in the US. This is one way of knowing you have the necessary experience but it hardly seemed the right tactic for us. Recruiting physicists from top centres in the US using Agenda for Change wages and the Manchester climate would be a challenge!

Our plan was to recruit and train, and key to this was early recruitment and comprehensive training. Initially, we increased the number of physicists, radiographers and dosimetrists involved in the detailed planning of the centre and then progressively recruited in advance of the clinical service. The training programme required needs both informal and formal links to centres overseas. In the early phases of the project, many visited a wide range of overseas centres. In the latter stages, the training has been more concentrated around the equipment manufacturer’s formal programmes and other Varian proton therapy sites. This has been accompanied by detailed site-specific clinical training with expertise brought in from clinical centres.

Although we upped the number of training places at STP, there is no doubt that in preparing for a project of this size we have used the time of some of our most experienced physicists and there is an effect on the radiotherapy service. However, we have also given a number of staff great opportunities to expand their knowledge and be part an exciting new service.

My observation would be that although proton therapy is different to conventional radiotherapy, modern proton therapy shares many of the same skills and staff well versed in advanced radiotherapy can bring much to proton therapy. So do not overstate the importance of proton therapy experience; good advanced radiotherapy experience is just as important. The proton team in physics will soon be 20 strong with posts at consultant, principal and senior grades covering physics, radiographers, dosimetrists and engineers. This staff group will need to cover a 14-hour clinical day with time outside that for run-up QA and patient verifications.

**Think ahead**

My main message would be to plan your timeline as you generally find you need to start things earlier than you think. We procured a treatment planning system in 2015 so that we could install it in 2016 and use it whilst we develop the protocols for proton therapy. From August 2017, we are now effectively running a proton planning service to plan patients on the indication list 1 year in advance of the first clinical treatment. We will install a fresh hardware system into the proton build in 2018 and although this might seem a bit extreme, we will be ready to treat all the indications on the indication list when we open.

You need to consider how you are going to commission the dosimetry equipment in advance of having a beam. It is also important to consider radiation protection. The issue in proton therapy is measuring what are hopefully low doses of neutrons. How one does so is not obvious even to an RPA from a radiotherapy background.

**The centre**

Eventually there is a time when the project is a concrete reality rather than a paper exercise. At that point, time slowly starts speeding up and I anticipate that will continue until we open. Once equipment starts arriving and being set up there is no avoiding the reality. However, we have been working forwards to that reality for a long time so bring on 2018.

**DIRECTOR OF MEDICAL PHYSICS & ENGINEERING**

**PROFESSOR RANALD MACKAY**

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Ranald Mackay The Christie NHS Foundation Trust
Proton radiotherapy at UCLH

Vasilis Rompokos, Callum Gillies, Andrew Gosling, Alison Warry, Andrew Poynter and Derek D’Souza (University College London Hospitals) have been involved with designing and testing the huge new proton therapy centre in London.

Our new 11-storey building will be home to one of only two high-energy NHS proton beam therapy (PBT) centres in the UK – the other centre has been built at The Christie Hospital in Manchester. Each centre will aim to provide treatment for up to 750 patients per year (figure 1).

**Fun facts**

The building extends 28.5 metres (five levels) below ground for PBT and above ground there will be a six-storey blood disorders hospital. When the site reached the bottom it was estimated that the auditorium of the Royal Albert Hall could fit inside, making it one of the most complex buildings ever built in London. Each gantry weighs 120 tonnes and is three stories high. The building will require just over 44,000 cubic metres of concrete (approximately 17.5 swimming pools of Olympic dimensions), reinforced with approximately 8,000 tonnes of steel (approximately 632 double-decker buses).

**Radiation protection**

In designing the facility we have worked closely with architects and shielding experts in the building, as well as our neighbours in adjacent buildings, whilst also trying to house the substantial size of the equipment into a fully underground area. This has involved using a combination of concrete (of varying densities) and steel, as well as boron-loaded plastics to reduce the neutron doses.

We also intend to carry out environmental monitoring on air discharges once the PBT service is up and running.

**Providing physics services for PBT**

The number of proton centres built around the world has increased rapidly over the last few years. The reason behind this increase is the continuous realisation of the benefits and our understanding of proton therapy, as well as the development of new technologies.

Trying to allocate resources to projects that will lead to the development of new techniques and protocols, whilst they are still relevant in the future of such a fast-evolving field, is one of the challenges.

**Commissioning measurements**

The team participated in depth dose measurements at experienced proton centres abroad to compare parallel plate chambers of different diameters against Monte Carlo simulations. During that time, spot size and position measurements were also acquired comparing a scintillation detection system with film (figures 2 and 3).

**Linear energy transfer**

One of the main concerns in the literature is the increased linear energy transfer at the end of the proton range that translates to an increased RBE. Our group has worked closely with UCL to investigate and understand the effect on a sample of brain cases (figure 4).

**Characterising the TPS parameters for inverse optimisation**

Proton treatment planning systems have a range of parameters that can be altered during optimisation. Altering these parameters changes the starting condition of the solution. The team is trying to characterise the effect of these parameters based on metrics of the dosimetric quality of the final plans. The effect of spot spacing is shown in figure 5.

**Patient-specific QA measurements**

During the operational hours of a proton centre, a significant amount of time is spent on patient-specific QA measurements. The team is developing scripts to extract and analyse data from the DICOM plan files, score metrics, quantify the complexity of the plans and investigate if there is a correlation to QA pass rates (figure 6). The scope is to develop a tool that will help planners predict if a plan is overly modulated, quantitatively compare plans designed using different techniques, and investigate the feasibility of reducing the time used for QA on the gantry.

**Developing a robust treatment planning protocol**

Robustness is probably the most commonly used word in the proton literature over the last few years. Flavours of robustness must exist in every element of a developing treatment planning protocol. The selection of number of...
FIGURE 5. The effect of spot spacing on conformity index (CI), homogeneity index (HI), the volume of 50 per cent isodose line and the average monitor units

Collaboration with other centres
As part of the preparation for opening the centre we have been working with European and American colleagues, and particularly with The Christie group, to consider the most efficient way to deliver quality assurance both of the beamline/gantry and for patient-specific QA. We will undertake more measurements initially to establish the stability and reliability of the system and devise a series of tests, utilising the R&V system. We aim to perform daily QA in around 30 minutes per gantry to have confidence that the beam is being delivered consistently. There is a paucity of commercial equipment on the market for daily measurements so other centres have had to adapt photon equipment to monitor proton beams. Some proton beam therapy vendors allow access to the log files produced by the system after the delivery of a plan. These files contain information on the accuracy of the actual beam delivery and can be compared with that intended. As with linacs, these can be used to ensure that the equipment can deliver the treatment modelled; however, it is essential that the limitations of the self-monitoring system are understood. We will look to work closely with equipment suppliers to ensure that we can find a method to achieve this in a drive for improvements in efficiency in the treatment pathway and accuracy of the final treatment delivery.

FIGURE 6. Field-specific data extracted from the DICOM-ION file, presenting the pattern of spot delivery

FIGURE 7. Robustness analysis for the CTV of a head and neck case
Paediatric molecular radiotherapy at UCLH

Dr Matthew Aldridge and Mark Gaze (University College London Hospitals) are involved in several trials which aim to treat Paediatric Neuroblastoma

Molecular radiotherapy (MRT) is the delivery of radiation to malignant tissue using a radiopharmaceutical targeted to molecular sites and receptors. The first use of $^{131}$I as a treatment was reported in 1941. In recent decades, the number of molecular radiotherapy administrations has increased significantly, as has the range of radiopharmaceuticals available. Optimisation of treatment has been aided by personalised, dosimetry-based treatment planning and verification of the absorbed dose delivered, especially within clinical trials. The value of dosimetry is described in a recent document from the EANM Internal Requirements to perform dosimetry presented in the previous issue of Scope. The aim of this article is to highlight the value within paediatric oncology.

**Work carried out at UCLH**

UCLH is currently one of two recognised UK centres offering paediatric molecular radiotherapy, alongside Royal Marsden. It is an interdisciplinary practice, with key contributions from clinical and paediatric oncology and nuclear medicine. We are fortunate to be equipped with two age-appropriate therapy rooms with the advantage of adjacent comforter and carer support rooms (figure 1). Fully trained paediatric nursing and medical ward staff are essential for the treatment of children, as are co-located nuclear medicine facilities for diagnostic and post-therapy imaging.

We are a national tertiary referral centre with particular expertise in the treatment of paediatric thyroid cancer and neuroendocrine tumours, including neuroblastoma, and an enlarging paediatric molecular radiotherapy clinical trials portfolio.

Neuroblastoma is a neuroendocrine tumour that arises in the sympathetic nervous system, resulting in tumours in the adrenal glands and/or sympathetic ganglia. Although only about 100 children in the UK are diagnosed each year with neuroblastoma, it is the most common solid tumour in children occurring outside of the brain. It is 8 per cent of the total number of children’s cancers, yet accounts for 15 per cent of paediatric cancer deaths.

Disease staging is based on metastatic spread and image-defined risk factors. Assignment to low-, intermediate- or high-risk groups is based on stage, age and tumour biology. Patients with low- and intermediate-risk disease have 5-year survival rates > 90 per cent, but more than half of all patients present with high-risk disease. Only around one-third of this group become long-term survivors.

Treatment of high-risk disease is complex, consisting of both systemic treatments designed to eradicate metastatic disease (induction and high-dose consolidation chemotherapy and immunotherapy) and local treatments for the primary tumour (surgery and radiotherapy). Not all patients respond well to initial chemotherapy – about 25 per cent are poor responders classed as having refractory disease. These patients have a reduced likelihood of cure. Following apparently successful first-line treatment, a significant proportion will relapse. Almost all of these patients will die of their disease despite undertaking aggressive further treatment.

For these reasons, neuroblastoma remains one of the major challenges in paediatric oncology, and new and improved treatment strategies need evaluation in clinical trials.

Molecular radiotherapy with $^{131}$I-mIBG is established in the treatment of neuroblastoma as a late-stage therapy option (figure 2), and whilst response rates are noted, there is recognition of a need to further optimise the treatment pathway. Historically, most reports of mIBG therapy have focused on the administered activity, and full tumour dosimetry has not been undertaken. Future trials...
will utilise $^{111}$-mIBG as a component of multimodality treatment schedules. As it is likely that those tumours receiving a higher radiation absorbed dose will respond more favourably, resulting in improved survival, it is essential that future trials include comprehensive dosimetry to test the hypothesis that there is a dose–response relationship.

Medical physics has a huge role to play throughout the patient pathway to include:

1. optimisation of both established imaging techniques, including CT, MRI, $^{111}$-mIBG planar imaging and SPECT and PET/CT, for diagnosis, staging, response assessment and follow-up (and also established treatment techniques including external beam and molecular radiotherapy), and

2. development of innovative imaging platforms and novel radiotracers, as well as development of advanced external beam radiotherapy techniques and evaluation of new therapeutic radiopharmaceuticals. Radiation protection and adherence to regulatory aspects are vital to the effectiveness of the service.

We are fortunate to receive financial support from a range of charities for our clinical research in molecular radiotherapy for neuroblastoma. This includes J-A-C-K (Joining Against Cancer in Kids), Cancer Research UK and INBRACED (International Neuroblastoma Research and Collaboration for Effective Delivery, a consortium of J-A-C-K and Solving Kids’ Cancer Europe and USA). This support from J-A-C-K to UCLH arose, in part, from our efforts to help one of our previous patients who had strong links within the Metropolitan Police, using $^{111}$-mIBG as targeted radiotherapy. Whilst our patient sadly lost his battle to neuroblastoma, the treatments proved palliatively effective.

The role of clinical trials in childhood cancer is essential, and 60 per cent of children with cancer now participate in clinical trials as part of their treatment, compared with 5 per cent of adults with cancer. There is tremendous potential to improve the effectiveness of molecular radiotherapy treatment through research using dosimetry. This is reflected in two international, multicentre trials about to commence, with UCLH the lead centre with regards to the molecular radiotherapy aspect of the trials.

**MINIVAN**

Immunotherapy with anti-GD2 monoclonal antibody treatment is routinely used in the treatment of high-risk neuroblastoma. In addition, anti-PD1 monoclonal antibodies have been used successfully in the adult population for malignant melanoma and renal cell carcinoma, amongst other diseases. Whilst these agents have been used successfully as individual treatments, the MINIVAN trial will combine the two for the first time in neuroblastoma. This is a phase I study of $^{111}$-mIBG followed by Nivolumab (an anti-PD1) and Dinutuximab Beta (an anti-GD2) in children with relapsed or refractory neuroblastoma. This is a collaboration between UK sites (Southampton, UCLH), Germany (Greifswald) and the USA (Madison, Wisconsin). The trial will determine the safety and tolerability of this innovative combination of agents.

**VERITAS**

Another trial will be the first European randomised trial to use $^{111}$-mIBG in one of the treatment arms for refractory neuroblastoma. A key feature of VERITAS (meaning ‘the truth’) will be the use of $^{111}$-mIBG earlier in the treatment regime (in refractory rather than relapsed patients), with more potential for curative outcomes. Vital to both of these trials is the appropriate acquisition of multiple (a minimum of three, ideally more) post-therapy imaging sessions in order to accurately map the biokinetics of the tracer within both tumour lesions and organs at risk. It is hoped to move towards the conventional radiotherapy model of knowing accurately the doses received by the target, and also the organs at risk. This should enable the therapeutic ratio to be effectively maximised.

These exciting challenges are in keeping with the increased recognition of MRT and the formation of groups such as the UK Internal Dosimetry Users Group (IDUG), IPEM working groups, the EANM dosimetry task force and NPL MetroMRT. One of the key roles of these groups is to harmonise methodology, both in the context of established MRT techniques and those within multicentre trials.

Within UCLH, the neuroblastoma research outlined above will only serve to add to our existing portfolio of novel methodology in the area of paediatric oncology research: LuDO (a phase II trial of $^{177}$Lu-DOTATATE for relapsed and refractory neuroblastoma, following our novel use of $^{68}$Ga-DOTATATE PETCT for demonstrating somatostatin expression in neuroblastoma (figure 3)), $^{131}$I-mIBG (a PET CT and PET MRI imaging study including a biokinetic substudy to support the dosimetry of mIBG treatment), and RIT (a trial assessing $^{90}$Y-labelled anti-CD66 radiolabelling as an alternative to total body irradiation for bone marrow transplant conditioning in cases of relapsed leukaemia).

The challenging nature of this patient cohort requires a high level of teamwork, as well as adhering to our other Trust policies of safety, kindness and improving, pulling together a wide range of disciplines; clinical oncology and nuclear medicine clinicians and scientists, and specialist radioisotope radiographers. Patient care is coordinated through a weekly MRT multidisciplinary team meeting, discussing individual cases, taking into account the clinical and holistic needs of the patient and their family.

Children with neuroblastoma are well represented in social and national media, and recent cases have been particularly prominent. We are grateful for support from parents’ organisations like J-A-C-K and Solving Kids’ Cancer, as well as more established funding routes like NIHR and Cancer Research UK, which enables us to undertake this vital research and development work.

**CLINICAL SCIENTIST**

**DR MATTHEW ALDRIDGE**

Matthew works in radiotherapy physics and nuclear medicine.
Inventories of medical equipment seem to steadily increase in number each year; the purchase of new equipment exceeding the decommissioning of older, possibly obsolete equipment. As the inventory grows, the process for the selection and prioritisation of medical equipment for replacement inevitably becomes an increasingly arduous task. How do you select which equipment over which? What are the clinical priorities? Who gets to decide or is it a case of who is the focus of the moment?

Over the last 2 years, we have developed a two-stage process for the replacement of equipment at Lancashire Teaching Hospitals that takes into account both technical and clinical considerations, producing a schedule of equipment proposed for replacement within a yearly budget cycle. The methodology was first proposed as a case study by Hegarty et al. and initially developed for medical equipment alone. However, the process now includes non-clinical submissions from other technical areas which are added in the latter stages of the process utilising the same methodology.

The two-stage process consists of technical and clinical assessments.

Technical performance aspect
In considering what technical factors should be taken into account, the ease in obtaining the data needs to be carefully thought through. Whilst database queries can be designed to interrogate the department’s Medusa database, good-quality external data can be more difficult to come by. In an ideal world manufacturers would provide good timely notice of their intention to cease support of certain models and the industry would always communicate these to the same position in the organisation. Arguably, this need for communication from the manufacturer is the most important factor.

In practice, the process timetable can result in equipment not being included as a consequence of late notice given by the manufacturer, or not communicated to the relevant position inside the organisation. In this case it is always wise to have a capital contingency fund agreed should continued use of the equipment be dependent upon ongoing manufacturer support for service delivery. Note that capital replacement funding is typically only available to replace individual equipment items of over £5,000 in value, so equipment of less value is not considered and must be replaced if necessary out of revenue monies.

The technical considerations chosen are:
- Expected life: equipment is assigned a technical life length of 7, 10 or 15 years based on the Department of Health’s EstManCode. Typically, small handheld equipment is 7 years, installed fixed equipment 15 years and everything else 10 years. This data is set during acceptance of the device type to ensure consistency.
- Published end of life: the date where the manufacturer cannot offer full maintenance support for the product. Contracts on offer move to ‘best effort’ with no guarantee of part availability. This information is supplied ad hoc by manufacturers and is attached to the specific model type in the database.
- Condition and support: the equipment’s overall condition and whether it can be supported by the manufacturer (even on a best-effort basis), making it technically obsolete. Condition is gauged during maintenance activities and support from attempts to source parts and service. It is dependent upon engineers’ observations, assessments and interactions to update the database.
- Reliability: the number of technical jobs undertaken in the last 12 months. Equipment under 3 years old is excluded, allowing for ‘teething’ issues. This data is sourced from interrogation of the department’s database.

Table 1 shows the criteria applied to these aspects and the associated score attached to it. Database queries are run and data extracted, with the highest score of the four aspects being carried forward as a technical replacement score. Those scoring a 3 or above are carried forward to the next stage in spreadsheet form. The spreadsheet ensures a fixed working point, preventing day-to-day operations affecting the scores carried forward.

Clinical aspects
The initial proposal was for clinical staff to score all their equipment and to keep the scores current, allowing scores to be dynamically changed so they would be reflecting clinical needs. It quickly became clear that clinical staff would not have the time available to do this task, so instead they were tasked with scoring the much smaller output that comes out of the technical stage.

Having provided the clinical management of the Trust with the equipment flagged up at the technical stage, they were asked to use the scoring in table 2 to identify a priority for replacement within the clinical specialities they were responsible for.

The clinical aspects chosen reflected the users’ needs and impact of the equipment on the department, along with the consequences associated with it:
- Confidence, the assurance that the equipment will work as intended when called upon.
- Quality, the assurance that the output/ treatment/function will be as intended.
- Efficiency, the assurance that the equipment does contribute to any service delay and possible financial consequences.
- Compliance, whether there are any clinical professional bodies that recommend replacement after a given operational life.
- Clinical consequence, definitions specified by the NPSA on the impact on the safety of patients, staff or public.

The clinical users and management are best placed to identify the scoring here because they are the owners and users of the equipment. They are aware of the clinical activity plans and pressures that dictate what equipment is needed and its current limitations. They were free to add equipment that was not listed at the technical stage, along with relevant reasons for doing so.

Using the familiar 5 × 5 risk assessment style, the users were asked to identify their highest scoring impact and multiply it by the associated consequence. This yielded
the clinical priority score for each item of equipment, which was recorded along with a brief comment on consequences, both to the clinical service and the patient, if non-replacement occurred.

**Moderation**

The natural temptation to increase scores a little was addressed by a moderating stage in the process. Once all clinical scores had been returned, clinical representation from all areas of the Trust met and reviewed the scored list of equipment, including the comments on consequences which provide context to the score. This is an important stage in the process as it produces corporate

**Addition of non-clinical equipment and submission for funds**

At this stage of the process, bids from other departments such as Estates and IT are added to the overall bid package of capital monies required. They are kept separate for clarity, due to a regular risk matrix for the risks and probabilities being used. These need to be clearly understood as non-clinically assessed and so are included as part of a larger submission to the Trust board for financial approval and release of capital monies. Of course, in times of financial austerity the amount of money required for the replacement programme may exceed that available. In this case, the clinical prioritisation of medical equipment becomes important as it allows the board to make clear and informed evidence-based decisions using the clinically assessed scores. It may be that funding only allows replacement of those assets scored at 15 or above, in which case the board members will choose to accept the remaining risks, being fully informed of them.

**Conclusion**

We have presented a process with both technical and clinical involvement for the identification and prioritisation of equipment for replacement. A technical matrix identifies equipment requiring replacement. This then informs clinical management who in turn produce a consequence statement and a clinical priority score with the assistance of a moderated by clinical peers and an agreed bid list.

**TABLE 1**

<table>
<thead>
<tr>
<th>Score</th>
<th>Expected life</th>
<th>Published end of life (EOL)</th>
<th>Condition and support</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;2 years to technical life end</td>
<td>Not advised or &gt;2 years to EOL</td>
<td>Good condition and supported by company</td>
<td>0 reported faults per annum</td>
</tr>
<tr>
<td>2</td>
<td>Between 1 and 2 years to technical life end</td>
<td>Between 1 and 2 years to EOL</td>
<td>Satisfactory condition and supported by company</td>
<td>1–3 reported faults per annum</td>
</tr>
<tr>
<td>3</td>
<td>Less than 1 year to technical life end</td>
<td>Less than 1 year to EOL</td>
<td>Good/satisfactory condition but not supported by company</td>
<td>4–5 reported faults per annum</td>
</tr>
<tr>
<td>4</td>
<td>Technical life end exceeded by up to 2 years</td>
<td>EOL exceeded by up to 2 years</td>
<td>Poor condition but supported by company</td>
<td>6–7 reported faults per annum</td>
</tr>
<tr>
<td>5</td>
<td>Technical life end exceeded by more than 2 years</td>
<td>EOL exceeded by more than 2 years</td>
<td>Poor condition and not supported by company</td>
<td>&gt;=8 reported faults per annum</td>
</tr>
</tbody>
</table>

**REFERENCES**


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### TABLE 2

#### Clinical impact
- **No issues**
- **Occasional minor concerns**
- **Occasional issues giving concern**
- **Regular issues giving concern or requiring intervention**
- **Regular (weekly or greater) performance issues**

#### Confidence
- **No issues**
- **Occasional issues**
- **Infrequent/minor issues**
- **Regular queries on or low quality of data/results/tests**

#### Quality
- **Within compliance recommendations**
- **At the limit of compliance recommendations**
- **>1 year out of compliance recommendations**
- **>2 years out of compliance recommendations**
- **>3 years out of compliance recommendations**

#### Efficiency
- **In service, unable to provide service**
- **In service, provides data quality/safety**
- **In service, inadequate data quality/safety**
- **Regular issues, inadequate data quality/safety**

#### Compliance
- **No recommendation for replacement**
- **Minor injury requiring limited intervention**
- **Moderate injury requiring medical intervention**
- **Major injury leading to long-term incapacity**
- **Incident leading to death**

#### Compliance reason
- **An event which impacts on a small number of patients**
- **An event which impacts on a large number of patients**
- **An event which impacts on a number of patients**
- **An event which impacts on a number of patients**

#### Impact on the safety of patients, staff or public
- **Mild injury requiring no/minimal intervention**
- **Moderate injury requiring limited intervention**
- **Major injury requiring extensive intervention**
- **Death**

#### Clinical specialties
- **Identifying the priority for replacement by clinical specialities**
Proton Partners International: transforming care

Professor Karol Sikora (Proton Partners International Ltd) is committed to providing innovative cancer care in oncology centres across the UK, with a comprehensive range of cancer treatments.

There is a pressing need to make specialised cancer care more accessible worldwide, and high-energy proton beam therapy can play an essential role in delivering better care. Proton Partners International Ltd is a company in the vanguard of advancing high-energy proton beam therapy in the UK and was formed in response to the growing global demand for such specialised treatment. The company, set up in 2015 by international cancer and healthcare specialists including myself, is contributing towards the broader research effort and clinical innovation in cancer care. The vision of Proton Partners International is to create a better future for patients by developing a network of cancer centres, committed to providing innovative cancer care.

As we know, protons deliver the same damage to cancer cells as radiotherapy; however, they can be controlled to stop at a defined point in the body. There are more than 150,000 cancer patients in the UK every year who are treated with radiation therapy, and at least 10 per cent of these patients could be better treated with proton beam therapy. This is a key debate on the supply and demand for proton beam therapy. The range of published estimates for the utilisation of protons in radical radiotherapy ranges from 1 per cent (UK, NHS) to 20 per cent in the US. Recent policy studies from several European countries indicate a 10–15 per cent utilisation of protons in patients treated with radical radiotherapy and this is now the basis of health department strategic planning in Holland, Germany, France, Italy and Scandinavia. Comparative estimates would suggest that 10–20 proton beam therapy treatment rooms would be required for Britain to ensure that 10 per cent of patients currently receiving radical radiotherapy would receive protons. It is clear from this that unless there is an urgent policy change, the overall quality of British radiotherapy will fall below European levels by 2020.

We are set to build at least five centres across the UK within the next 4 years. Currently, the company has a fully operational centre in Newport, South Wales, and is building a further three centres in Northumberland, Reading and Liverpool, with an additional site under consideration in London. It is the company’s ambition to have a Rutherford Cancer Centre within 90 minutes of the front door of 75 per cent of the UK population by 2021, meaning that patients will not have to travel for several hours or abroad for cancer treatment that is best delivered close to home. The company has also made an investment in Abu Dhabi to acquire an oncology business with a view to building a proton therapy centre alongside the existing clinic. This would not only allow for patients from the Middle East to receive world-class cancer treatment but also for Rutherford cancer patients when abroad.

Proton Partners International’s oncology centres are known as Rutherford Cancer Centres, in tribute to the renowned scientist Ernest Rutherford’s contribution in identifying and naming the proton in 1911. At each centre, we aim to treat up to 500 patients annually. In addition, the centres will offer imaging, chemotherapy, radiotherapy, immunotherapy and a range of supportive services including survivorship and recovery. The centres will be staffed by one clinical team across the multiple sites who will all work from a shared central system. This will allow oncologists to work remotely and treat patients on any of the Rutherford sites. Full integration of clinical systems across all sites will allow for paperless working as all patient data will be stored and analysed at one location. Treatment will be available to medically insured private patients, self-paying patients and patients referred by the NHS.

The single-room Proteus®ONE proton beam therapy system will be installed at each of the Rutherford Cancer Centres. The system, installed and maintained by IBA (Ion Beam Applications S.A.), offers the most advanced proton therapy technology on the market. The compact design of the Proteus®ONE system makes proton therapy more affordable by reducing energy consumption, which in turn minimises the impact on the environment. The system, equipped with Philips Ambient Experience, allows for advanced imaging techniques to be carried out. Tumours are targeted with cone beam CT, a volumetric visualisation of the tumour and the body. The system has been designed to optimise the patient experience by providing a comfortable and calming environment whilst reducing the time it takes staff to position patients for their treatment. It is also equipped with pencil beam scanning (PBS), which enables highly precise scanning, layer by layer, pixel by pixel, to perfectly match the shape of the patient’s tumour.

By offering a variety of therapies, our centres will deliver a fully comprehensive level of cancer care, tailored to fit the different needs of each patient – something not available in the UK at the moment. More patients will benefit from better diagnosis and newer treatments, with a greater emphasis on the quality of life.

Our company also has a number of interesting developments in the pipeline. We will undertake a major genomics research programme with the Life Sciences Accelerator in Liverpool. We are also working with the University of Liverpool on a genomics programme to collate, analyse and distribute data from its treatment centres. In addition, we have announced a 2-year collaborative research project with the university to develop a new measurement system, known as a 3D water phantom, which will further improve the accuracy of proton beam therapy treatment. We have further demonstrated our commitment to innovation by creating two subsidiary companies, Rutherford Innovations Ltd and Rutherford Diagnostics Ltd, which will allow for Proton Partners International to positively contribute to the research effort without disrupting the cancer services we already offer.

Indications for proton beam therapy are evolving rapidly and Proton Partners International will be at the forefront of this growth and will continue to invest in centres and innovation to maintain its position as a market leader. The next 25 years will be a time of unprecedented change in the ongoing battle against cancer and Proton Partners International are excited and proud to be part of this challenge.

MEDICAL DIRECTOR
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Towards absolute dosimetry in proton radiotherapy: Part I

Russell Thomas [National Physical Laboratory] writes the first article in a series, this time describing the beginning of an unexpected journey.

It was late on a dark and extremely wet November evening in 1999 when I was returning to London on the M1. What was I doing here? I could have been in the pub or working on one of my motorbikes. The rain was beating down on the windscreen so hard I could hardly see the lights of the car in front, let alone work out how close I was! I was vaguely aware of my passengers’ intense conversation regarding the meeting we had earlier that day, but frankly not taking much notice. I was more interested in trying to make sure that I stayed on the road without smashing into the back of the car in front. ‘... What do you think, Russ?’ I hadn’t got a clue what they had just asked me. I slammed the brakes on. ‘Cricket! Did you see that bloke swerve in front of us? No... Oh, anyway, sorry, what was the question?’ ‘Would you like to help us work on this proton project with Andrzej?’ And so began my involvement with proton dosimetry which would help shape my career for the next 20 years!

My passengers were two NPL colleagues, Frank Verhagen (now Professor and Head of Physics Research at MAASTRO Clinic, Netherlands) and Hugo Palmans (now in a joint role between NPL, UK, and MedAustron, Austria). That day we had visited a lovely chapel called Dr Andrzej Kacperek, Head of the Douglas Cyclotron Facility at Clatterbridge Cancer Centre, to discuss a possible collaboration in the area of proton therapy and more specifically the issues surrounding dosimetry. I had only heard about proton therapy the year before in the viva for my MSc project. The examiner, one Professor Lilliscrap, had surprised me with a question regarding my thoughts and knowledge in this area – I didn’t impress him.

This time, talking with my colleagues and Andrzej, I had a far more comfortable and interesting chat about this area. It was clear that whilst the perceived benefits of proton therapy for clinical treatment could be impressive (if perhaps unproven), the accuracy of dosimetry and traceability offered plenty of scope for improvement. It is probably worth mentioning at this point that, as the UK’s National Measurement Institute, NPL is responsible for building, developing, maintaining and disseminating the UK’s primary standards. Perhaps the easiest explanation to understand in terms of why we exist is ensuring that everyone uses the same unit of measurement for the metre, kilogram or second (within appropriate uncertainties, of course). However, our group is responsible for the development and implementation of standards for radiotherapy treatment, and the quantity of interest in radiotherapy is the dose received by the patient defined in terms of the unit the Gray (Gy).

**Difficulties involved**

The primary standard for absorbed dose for external beam radiotherapy is a calorimeter. This device is based on the design proposed by Steve Doman back in the 1980s. The basic principle is to measure the temperature rise caused by the heating effect of a typical patient fraction from the interaction of the radiation with a given material (typically water or graphite).

The primary standard for MV photon therapy held at NPL is a graphite calorimeter which realises the quantity of absorbed dose through a measurement of temperature rise, and hence energy deposited, due to the radiation. The ‘dose’ we deliver is similar to that given for a typical patient treatment fraction (i.e. 2 Gy), which gives a temperature rise of approximately 2.8 mK. Which is, quite frankly, tiny!

There are considerable difficulties in setting up an instrument to the required level of accuracy to successfully make these measurements within acceptable uncertainties. Because of the tiny temperature rise we have to isolate the device carefully from the influence of temperature change around it. The side effect of this is that after we have irradiated the calorimeter, we have to wait a considerable amount of time before we are able to conduct another run. This means that we may only achieve a handful of runs in an entire day, which of course does not give us great statistics on our measurements. As calorimeters are complex and difficult to operate, hospitals use simpler detectors like ionisation chambers that are calibrated against the primary standard calorimeter at NPL – these ionisation chambers are referred to as secondary standards.

Now, you may have noticed that we don’t see too many graphite patients for treatment, so we have to convert the absorbed dose realised in graphite to absorbed dose to water. A far more useful quantity for clinical use, it is not exactly what we would like to give to the clinic but it’s better than trying to convert exposure measurements to absorbed dose, which is what we used to do prior to the introduction of the IPEM MV Code of Practice, the world’s first absorbed dose-based protocol in 1990. Work is progressing on something more clinically relevant, but that’s another story for after I retire...

It has long been recognised that when calibrating secondary standard ionisation chambers, the preferred method is to conduct the cross-calibration in the same beam being used in the clinic or at least a beam of similar characteristics. Hence, at NPL we have two Elekta linacs available to conduct calibrations across the full range of energies used clinically. The hospitals then send their secondary standards to NPL and we conduct a number of functional checks to ensure that the chamber is operating correctly and the chambers are calibrated in terms of absorbed dose to water, and then returned to the hospital for in-house measurements.

**Ensuring consistency**

In terms of traceability for MV photons, we have arguably perhaps the most consistent service across our users in the world. This is due to the realisation of dose from the same primary standard over the past 30+ years, the use of a single recommended secondary standard ionisation chamber type and implementation of the recommendations for reference dosimetry from the IPEM Code of Practice. Moreover, dosimetry audit, both regional and national, has played its part in improving consistency of the dose disseminated through to the radiotherapy department, and a recent review of reference dosimetry audits performed over the last 20 years by NPL has helped to demonstrate this assertion.²

We would like to have this same rigorous and consistent traceability across the
country for all modalities, but in the case of protons, the numbers involved have not made it necessary nor economically sensible to do so, since for almost 30 years there has been only one proton centre in operation in the UK.

**Application to proton therapy**

At present, a calibration service based on a primary standard calorimeter for the direct determination of absorbed dose to water for proton beams does not exist anywhere in the world. Ionisation chamber dosimetry under reference conditions is performed based on chambers calibrated in other beam modalities; for example, Cobalt-60 beams. The calibration can then be converted via a number of conversion and correction factors, mainly theoretically derived, to give a calibration in the beam of interest. Consequently, the uncertainties are large: 2.3 per cent and 3.4 per cent for protons and heavy ions beams (at 68 per cent confidence level), respectively, when compared to a combined uncertainty of just 1.5 per cent (at 95 per cent confidence level) for photon beams. With multiple high-energy proton centres opening soon in the UK, there is a pressing need to improve the situation regarding proton dosimetry and a desire to reduce the uncertainty to a level comparable with that obtained for photon beam treatments.

Since NPL did not, and still does not, have a proton beam facility, perhaps we could transport the primary standard to the clinical proton facilities in order to conduct the calibration? This is not possible for a number of different reasons with the existing design of primary standard, so a small-body prototype portable calorimeter (figure 1) was built to test the feasibility of making measurements with a calorimeter directly in the Clatterbridge proton beam. Trying to conduct calorimetry measurements outside of the primary standards laboratory is fraught with problems; however, we were able to build on the work of McEwen and Duane who had previously built and operated a portable proton calorimeter in a number of UK radiotherapy departments. This first prototype proton calorimeter provided us with promising results and also confirmed for us the need to improve proton reference dosimetry. Figure 2 shows the ratio between dose to water obtained with the prototype proton calorimeter and dose to water obtained with various ionisation chambers calibrated in Cobalt-60 and high-energy electrons, converted to a proton beam calibration by applying the procedure formalised in IAEA TRS-398 (the current protocol in use in clinics worldwide). The ratio could vary by up to 4 per cent depending on the beam type and ionisation chamber used, and this was in optimal conditions in the same proton beam. It should be remembered that ICRU 24 recommends that the dose delivered to the patient should be within 5 per cent (95 per cent confidence level) of the prescribed value, with some literature stating that this should be within 2 per cent.

Based on experience obtained with this prototype, a primary standard level graphite calorimeter for proton beams was designed and built by NPL. This calorimeter will enable the provision of a direct absorbed dose to water calibration service which will follow the recommendations and procedure laid out in a forthcoming IPEM Code of Practice for reference dosimetry in proton beams.

**Looking forward**

With the imminent opening of the new high-energy centres, all of us involved in the provision of radiotherapy in the UK should wish to maximise the unique opportunity we have of demonstrating the benefits of proton therapy. The improvements we propose should, amongst other things, maintain consistency of dose across all UK proton centres (both NHS and private) and allow us to more easily compare clinical trials involving photon and proton treatment. There will still only be a relatively small number of patients receiving proton therapy so reducing uncertainty in any aspect of the treatment delivery to the patient will help when analysing outcomes. There is also considerable interest in the development of our primary standard and service from overseas centres. This could perhaps play a helpful role in increasing recruitment of patient numbers into clinical trials from across the globe.

In the next issue we will describe in more detail the design of the UK primary standard proton calorimeter and discuss the development and rational behind the forthcoming IPEM Code of Practice for Proton Dosimetry.

**REFERENCES**


Word trending: identifying patterns from free text

Being able to spot trends in data is an important skill for clinical engineers. Finding trends in adverse incident reports or service reports can, for example, help identify when a certain medical device model has an inherent design flaw, or if a certain hospital department is systematically misusing equipment. The difficulty in identifying trends, however, is its reliance on the quality, extent and manner of data collection.

At King’s College Hospital, medical device service reports are maintained on a Trust-wide medical equipment database. For each equipment service carried out by the engineers, details including the manufacturer of the equipment, the model and the department to whom it belongs are recorded. Engineers are also able to enter, in free-text form, any actions they have taken during the service.

When details are restricted to a limited list of options, it enables us to easily analyse the data. For instance, we can review historic service reports to see which models of medical device are associated with particularly high rates of breakdown. However, for information recorded as free text, analysis is far more difficult. Each engineer will naturally record information in a different way, and so the structure of any two free-text entries (even if they are describing the same thing) may vary significantly. Therefore, current trending using service report data is generally limited to certain fields within the equipment management database.

Here, a method to perform trending analysis of free-text fields in service reports is described.

Data extraction
Medical device service reports covering a 1-year period were extracted from the medical equipment database. Within each service report is a free-text field where engineers enter what actions they have taken during the service procedure. In total, just over 10,000 action fields (each a free-text string) were analysed. Each free-text string contained up to 100 words, giving a total of nearly 170,000 words.

The method is an objective way to assess the frequency of words appearing in free-text data and to use those words for identifying trends.

Determining word frequency
Within Excel, each word was placed into an individual cell from its free-text string, and then the resulting matrix converted into a single column. The number of occurrences of each word could then be counted. A list of all words was ordered by frequency of the word’s occurrence within the service reports. Thus, at a glance, words that are likely to indicate a trend can be identified.

Trends from individual words
Identifying relevant words that occur most frequently in service data may not on its own be useful. However, those words can then be used to look for trends in the original service reports. For example, the number of times the word ‘loose’ occurs in service reports according to equipment type can be calculated (see table 1). Therefore, equipment types associated with service reports containing many

![Word cloud](https://www.jasondavies.com/wordcloud/)
It may be applied to any data collected in sufficiently large quantities, but, due to being free text, is otherwise difficult to analyse. There is subjectivity involved when deciding upon which words are relevant and caution must be used where words may have multiple meanings. However, beyond this, the method is an objective way to assess the frequency of words appearing in free-text data and to use those words for identifying trends.

### Summary

The method briefly outlined here is not restricted to the analysis of service reports. Occurrences of a word such as loose may indicate a systemic issue.

### TABLE 1

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>Occurrences of ‘loose’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slit lamp</td>
<td>12</td>
</tr>
<tr>
<td>Infusion pump</td>
<td>8</td>
</tr>
<tr>
<td>Tonometer</td>
<td>5</td>
</tr>
<tr>
<td>Multi-parameter module</td>
<td>5</td>
</tr>
<tr>
<td>Nibp-saturation monitor</td>
<td>5</td>
</tr>
<tr>
<td>Transport ventilator</td>
<td>4</td>
</tr>
<tr>
<td>Syringe driver</td>
<td>4</td>
</tr>
<tr>
<td>Patient monitor: multiparameter</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE 1.** The equipment types associated with service reports containing occurrences of the word ‘loose’. Only the equipment types with the eight most frequent occurrences of ‘loose’ are shown.

**REFERENCES**

1. Data → Text to Columns
   
2. =OFFSET(Matrix,TRUNC((ROW()-ROW(cell containing this formula))/COLUMNS(Matrix)),MOD(ROW()-ROW(cell containing this formula),COLUMNS(Matrix)),[1],[1])

3. =(LEN(data range)-LEN(SUBSTITUTE(data range,"loose","")))/LEN("loose")

**CLINICAL & BIOMEDICAL ENGINEERING EDITOR**

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Healthcare delivery in the UK today faces many challenges. The Institute of Economic Affairs (IEA) published a report in February 2017 calling for an overhaul in the way health and social care are delivered. The Royal Academy of Engineering (the Academy), together with the Academy of Medical Sciences and the Royal College of Physicians, have recently published a report highlighting the important role that engineers, and the systems approach they take to problems, can help in finding solutions to these challenges. This work was the continuation of a preliminary study led by the Chartered Institution of Building Services Engineers (CIBSE), the Institute of Healthcare Engineering and Estate Management (IHEEM) and the Institute of Physics and Engineering in Medicine (IPEM). Professor Mark Tooley FREng, current IPEM President, was a member of the working group in his capacity as a Fellow of the Academy.

The challenges
One of the main challenges that faces the NHS today is the current economic climate. Over the last decade, demand on the service has increased at a higher rate than available resources, putting the service under huge pressure. NHS organisations and departments are thus having to meet strict cost-improvement and efficiency plans, giving them little flexibility in managing their resources, especially staffing levels. And yet, despite all these pressures, it is essential that hospitals continue to meet a number of safety and performance standards in their service delivery. The introduction of any qualified provider initiative (AQP) can be seen as a challenge but also an opportunity at the same time, as it encourages a competitive market, as long as safety and performance are not compromised.

The Academy report proposes a model for applying such a systems (or system of systems) approach to health and care design and delivery, bringing together four key and complementary elements: people, systems, design and delivery, bringing together four technical and professional networks in virtual meetings, for example, and in systems for sharing information. We also have a number of rigorous training programmes in the medical and allied professions that continue to produce a very high-calibre and highly competent workforce. The UK continues to be a main focus for high-quality medical and scientific research, attracting top researchers from around the globe. We have a highly innovative and skilled workforce that is capable of adapting easily to meet new demands and pressures. It is therefore not surprising to see that new and emerging technologies are being adopted more and more in the NHS. Examples of such technologies include wearable devices, wireless technology, robotics, 3D printing, cloud computing, big data, the Internet of Things, genomics and proteomics, etc. The full impact of these technologies and others in the NHS is yet to be realised.

The opportunities
However, with all these challenges there are also opportunities that did not exist a few years ago. Rapid advances in information and communication technology have opened many doors. It has enabled clinicians to share data, images and documents readily from their desktops. It has made it easier to support professional networks in virtual meetings, for example, and in systems for sharing information. We also have a number of rigorous training programmes in the medical and allied professions that continue to produce a very high-calibre and highly competent workforce. The UK continues to be a main focus for high-quality medical and scientific research, attracting top researchers from around the globe. We have a highly innovative and skilled workforce that is capable of adapting easily to meet new demands and pressures. It is therefore not surprising to see that new and emerging technologies are being adopted more and more in the NHS. Examples of such technologies include wearable devices, wireless technology, robotics, 3D printing, cloud computing, big data, the Internet of Things, genomics and proteomics, etc. The full impact of these technologies and others in the NHS is yet to be realised.

Systems engineering thinking
However, all these opportunities must be brought together in a systematic way to bring about real change and improvement for the benefit of staff and patients. The Academy’s report explores how the engineering systems approach can be valuable to coordinate such change in healthcare systems. Engineers are trained to find solutions to problems using systems thinking. By understanding the problem space and various constraints, engineers assess different design values, continuously validate design options against the need whilst at the same time verifying their solutions with the specification. During the design phase, a good engineer thinks ahead and integrates his or her solution to later phases of the lifecycle such as incorporation, support and disposal. Engineers also spend considerable time and effort on risk assessment. This is usually carried out at the beginning of the lifecycle as it may influence the design, and is continuously being reviewed and updated during the development stages.

The Academy report proposes a model for applying such a systems (or system of systems) approach to health and care design and delivery, bringing together four key and complementary elements: people, systems, design and risk (figure 1). The task is to decompose the problem into these elements, think of the pertinent questions in each element and look at solutions. Although this sounds easy on paper, in practice all of these elements are interlinked (figure 2). All of the elements have to be fully understood in order for the system to work. The Academy report presents a number of case studies which highlight the application of this framework in practice.

Keynote session
On 9th October 2017, IHEEM hosted a special session during their annual
conference in Manchester to highlight and promote this report. Both authors of this article were invited to give keynote lectures from IPEM and the Academy’s perspectives on how systems engineering helps in our profession. The session was introduced by Pete Sellars, President of IHEEM. During these presentations, examples where systems engineering thinking helped solve some clinical problems were highlighted. With all of these examples, a systems approach was applied retrospectively to identify key issues, stakeholders and how to measure success.

Royal Academy of Engineering perspective

As outlined above, the breadth and scale of challenges facing the health and care systems in the twenty-first century are significant. Over the past two decades there have been a number of calls for a more holistic systems approach to handle the complexity in the system and to address the needs of a changing population. However, there have been few definitions of what this might mean in practice for health and care.

In contrast, engineers routinely employ a systems approach to their work. Indeed, an Academy report for the education system found that ‘systems thinking’ was a key characteristic of an engineering mindset. A systems approach allows engineers to work through the implications of each change or decision they make for the project as a whole, whether that is the design of a jet engine, delivery of the Olympic Games or development of a new medical imaging device. This project therefore set out to explore whether this engineering systems approach could be translated and applied to the design and improvement of health and care systems.

It was clear from the outset that this project could not be delivered by one organisation, or indeed one profession, in isolation and that an engineering approach could not be directly lifted and implemented in the health and care setting. Healthcare brings unique challenges, ways of working and culture when compared to many engineering systems. The Academy therefore recognised the need for a deeply collaborative and interdisciplinarian project. The resulting work built on an initial study by three professional engineering institutions (IPEM, IHEEM and CIBSE), and became a joint project between the Royal Academy of Engineering, the Academy of Medical Sciences and the Royal College of Physicians. Input was gathered through workshops with systems engineers, healthcare leaders and improvement professionals, ensuring that this work has been genuinely coproduced across professions. We hope that the result of this is a framework for systems thinking in a health and care setting that is rigorous, clear and relevant to professionals in the healthcare system.

However, the Academy doesn’t want this to be a report that sits unopened on shelves or on our website. Rather, we are looking to collaborate with project partners and others to implement and trial the approach in practice. The cross-sectoral collaboration that was central to the development of this work will be equally important to the successful delivery of the approach in practice.

While engineers in the healthcare sector can champion a systems approach, close collaborative working with clinicians, healthcare managers and transformation teams will be important for successful systems-based improvement initiatives. For example, members of the Academy’s working group are continuing to work with the Royal College of Physicians to integrate systems-based improvement initiatives. The Academy welcomes suggestions and proposals for further potential partnerships to trial and implement the systems framework presented in the Engineering Better Care report. Please contact Dr Nicola Eckersley-Waite, nicola.eckersley-waite@raeng.org.uk, for more information.

REFERENCES

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The third article in this series gave suggestions for producing a high-quality application to the National Institute for Health Research (NIHR) research training schemes. This article concentrates on the interview process and preparation. It includes a reminder of the importance of PPI from a patient representative and comments on dealing with feedback. These suggestions are distilled from information from research funders, senior researchers and successful applicants to NIHR personal award schemes.

Your local Research Design Service (RDS) may be able to assist with your interview preparation; for example, by reviewing your slides, your talk and Q&A.

Stage 2 of the application
If you are successful at stage 1 of the application process, you will be invited to complete the stage 2 application. Unlike many project/programme grant applications, with NIHR fellowships most of the detail is in stage 1. Do not treat stage 1 as an expression of interest – it is the bulk of the application.

The stage 2 application form requires the detail of the requested finances and their justification, an indepth description of the PPI work and the management arrangements for the research.

If you are a PhD-level applicant and the stage 2 written application is successful then you will be offered an interview. If you are applying at post-doctoral level or higher, your application will be sent for external peer review. These reviews and your stage 2 written application will be considered and, if successful, you will be offered an interview.

The interview
Interviews take place over 2 to 3 days on dates published many months in advance on the NIHR website. Each level of award has its own panel; the names and affiliations of the panel members are on the NIHR website.¹

The interview starts with a brief introduction by the Chair of the panel who will then invite you to give a 5-minute presentation. This is followed by 20 to 25 minutes of Q&A.

Two panel members will lead the Q&A. One will focus on your research proposal and the other on the applicant, including questions about your training and development. The Chair may offer the opportunity to ask questions to the rest of the panel and may explicitly invite the patient/public/carer member to ask questions as well.

Research the panel members for your award to gain an idea of their likely approach to questions.

Panel members are experts in their fields and are skilled in reviewing applications and interviewing, but the majority of them will NOT be physicists or engineers. It is critical to understand this so that your presentation and responses to questions are clear and intelligible.

Be aware that panel members will have between 20 and 30 applicants to interview over the course of 3 days. Recognise that you need to inform and persuade this diverse audience of the value of funding both you and your research.

The presentation
NIHR will send guidelines for the content of the slides that you will need to adhere to in order to be successful. The slides...
are submitted to NIHR a minimum of a week before the interview and cannot be changed at a later date. It is important to start preparing them as soon as the interview offer is received.

The presentation enables you to start your interview in control – you know the slides and the message you want the panel to hear.

You must keep to time (5 minutes) and you will be stopped if you overrun. A 5-minute presentation implies only 5 to 6 slides and speaking at around 1 minute per slide. The final slide will remain visible throughout the interview so ensure it has the take-home message for the panel.

Comments from panel observers and panel members on the characteristics of successful interviewees include:
- Enter the room with a smile and make eye contact.
- Stay calm.
- Admit if you do not know the answer to something.
- Ask for clarification if you do not understand a question.
- Try not to be defensive/aggressive/overconfident.
- If something has changed, discuss this with the panel.
- Listen to suggestions from the panel and interact positively with them.

There is often an opportunity at the end of the interview for the candidate to ask a question or update the panel on any changes or activity since the application was submitted. Prepare something positive to tell the panel about; for example, a recent publication, an invitation to speak at a conference or a promotion. This enables the interview to finish in a positive way.

Feedback
It is very disappointing to receive a rejection and it can feel personal, even though it is not. Most funding schemes have success rates of around 10-20 per cent and all academics have experience of having their research bids rejected. Whilst difficult, it is a good opportunity to develop the key skill of resilience and how to deal with feedback positively. This is a chance to improve the application so that it is exciting and convincing next time.

The NIHR fellowship schemes allow resubmission. In a resubmission the feedback must be clearly and comprehensively addressed, and a good explanation given of how the application has been changed.

Feedback is provided for all applicants. If the application is successful it is worth taking time to consider the feedback as it can assist in improving the quality of future bids.

Summary
This series of articles has described the NIHR fellowship schemes and has suggested approaches to produce a scientifically sound and engaging application. Information from a wide variety of sources on successful interviews has been synthesised and PPI covered in detail.3–5

Feedback
It is very disappointing to receive a rejection and it can feel personal, even though it is not. Most funding schemes have success rates of around 10-20 per cent and all academics have experience of having their research bids rejected. Whilst difficult, it is a good opportunity to develop the key skill of resilience and how to deal with feedback positively. This is a chance to improve the application so that it is exciting and convincing next time.

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Summary
This series of articles has described the NIHR fellowship schemes and has suggested approaches to produce a scientifically sound and engaging application. Information from a wide variety of sources on successful interviews has been synthesised and PPI covered in detail.3–5

Feedback
It is very disappointing to receive a rejection and it can feel personal, even though it is not. Most funding schemes have success rates of around 10-20 per cent and all academics have experience of having their research bids rejected. Whilst difficult, it is a good opportunity to develop the key skill of resilience and how to deal with feedback positively. This is a chance to improve the application so that it is exciting and convincing next time.

The NIHR fellowship schemes allow resubmission. In a resubmission the feedback must be clearly and comprehensively addressed, and a good explanation given of how the application has been changed.

Feedback is provided for all applicants. If the application is successful it is worth taking time to consider the feedback as it can assist in improving the quality of future bids.

Summary
This series of articles has described the NIHR fellowship schemes and has suggested approaches to produce a scientifically sound and engaging application. Information from a wide variety of sources on successful interviews has been synthesised and PPI covered in detail.3–5
Travel is said to help broaden the mind, and this was certainly the case with my first visit to China. My ex-colleague and current collaborator, Professor Dingchang Zheng (Anglia Ruskin University), made the key link between our two countries. The trip (including Sino-UK Symposium) in the north of the country and, secondly, a visit to Shenzhen (Department of Electrical and Electronic Engineering and Department of Science and Technology of China (SUSTech)) in the south. The programmes were very well organised with academic, social, cultural and amazing food themes intertwined. The overall trip was kindly funded by Professor Song Zhang and Professor Dongmei Hao from the College of Life Science and Bioengineering, Beijing University of Technology (BJUT).

**BEIJING AND SHENZHEN, April 2017**

Dr John Allen (Freeman Hospital, Newcastle upon Tyne) went to China to attend a physiological measurement symposium and an academic university visit, leading to new links.

**Sino-UK Symposium on Physiological Measurements and Clinical Applications, Beijing**

I attended the first ever Sino-UK Symposium on Physiological Measurements and Clinical Applications (21st April 2017) at the Gongda Jianguo Hotel within the BJUT campus. The symposium joined together researchers working in physiological measurement, particularly those interested in the peripheral pulse and pulse wave analysis. The hosts had kindly invited four speakers from the UK to talk about vascular optics, medical device development and pulse measurement and analysis: Professor Zheng, Professor Panayiotis Kyriacou (City University of London), Professor Stephen Greenwald (Queen Mary University of London) and myself. Many researchers from across China also attended the event.

The Symposium opened with a welcome message from Professor Zhang, followed by three introductory speeches from Professor Yu Chang (Vice Dean of College, BJUT), Professor Zheng and Professor Rugang Zhong (China Association of Medical Equipment). Their lead staff and UK visitors are shown in figure 1a. The introductory session included an award of a Certificate of Guest Professorship to recognise Professor Zheng’s contribution to developing educational and research collaborations between the UK and China (figure 1b). My talk opened the formal scientific session in which I gave an overview on the field of vascular optics, particularly microvascular imaging and photoplethysmography (PPG). Professor Kyriacou then gave a wide-ranging talk on the expert use of light in clinical monitoring and disease diagnosis, highlighting both opportunities and challenges. Topics included PPG and optical sensor design, skin hydration, neurointerfacing, NIRS cerebral oximetry, light interaction with tissue, optical and wearable sensors for the assessment of wellbeing. Professor Zheng then gave a fascinating overview of innovative medical technology used to assess arterial health, including the novel measurement of arterial compliance and related device

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**Panayiotis Kyriacou** (City University of London), **Professor Stephen Greenwald** (Queen Mary University of London) and myself. Many researchers from across China also attended the event.

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development and clinical validation stages. Professor Greenwald gave an overview of his wide-ranging research and development work on innovative methods in pulse measurements as well as the assessment of vascular endothelial function. Many excellent studies were presented at the symposium and it was clear from the discussions and lab visits that there was considerable interest in haemodynamics: cardiovascular measurement and modelling including transfer function models for the aortic pressure waveform, simulation of the pulse, detection of the pulse during exercise, control of the artificial heart and improving cardiac function recovery, and prediction of preterm labour using uterine electrohysterogram, as well as signal processing including mobile phone health and big data. During the Symposium, the hosts kindly presented their department to the guests (figure 2), with students showcasing their Masters-level research projects on medical device development and cardiovascular modelling. I came away with the solid impression about the importance placed by the host organisation/country on medical device innovation and MedTech.

Academic visit to Biomedical Engineering, South University of Science and Technology (SUSTech), Shenzhen

It was also a privilege to be invited to visit Professor Fei Chen (SUSTech) and present an extended talk on vascular optics to his research group (25th April 2017; figure 3). I also gained a detailed understanding of his areas of work and research opportunities, where he is studying speech signal processing, brain machine interface technology, biosignal processing and biomedical system modelling. The specific research includes:

1. Understanding the speech perception mechanism in adverse listening conditions and its language-specific difference, and developing a novel speech coding/enhancement strategy to improve speech recognition for normal-hearing listeners and hearing-impaired populations. Designing electrical stimulation-based brain–computer interface technology to restore hearing for hearing-impaired people.
2. Studying neural mechanisms and exploring neural correlates for patients with a communication disorder (e.g. hearing loss, autism), and designing a customised rehabilitation programme via an electrical/magnetic stimulation strategy.

3. Biomedical system modelling and bioinstrumentation for developing innovative non-invasive and continuous health monitoring technology.

Cultural activities

We were well looked after by staff and students who, on their days off from work, graciously made time to show us around their cities and various major historical cultural sites, along the way sampling many different styles of foods from across the country. Food wise, it seemed hard to beat that fabulous existentialist meal experience at the top of the Shenzhen skyscraper KK100. Places visited in Beijing include a walk on a section of the Great Wall, visiting the Old Summer Palace, Tiananmen Square, Tiananmen (Gateway of the Heavenly Palace), Chairman Mao’s Mausoleum and the Forbidden City.

Cultural experiences included a visit to the theatre to see gravity-defying acrobatics. In Shenzhen, I immersed in the vast China Folk Cultural Village and visited Sea World where Chairman Deng Xiaoping’s famous ship Minghua is landlocked, plus a challenging walk up to that very important statue of the Chairman himself. The industry of the people is to be applauded – Shenzhen is a vibrant city which, in just a few decades, has grown from a small fishing village to the Silicon Valley equivalent in the world of microelectronics.

Collaboration and ways forward

The international trip was excellent and an amazing life experience for me. New collaborative links and opportunities have been established. There is certainly common ground and interest in vascular optics and wearable sensors, for which the centres will continue to explore further resourcing of collaborative research and exchange visits to create wider opportunities for all.

FIGURE 3. Professor Dingchang Zheng, Dr John Allen and Professor Fei Chen at the Department of Electrical and Electronic Engineering and the Department of Biomedical Engineering SUSTech, Shenzhen
The 25th Annual Meeting of the International Society for Magnetic Resonance in Medicine (ISMRM) was held between 22nd and 27th April 2017 in Honolulu, Hawaii. Dr Kevin Ray (University of Oxford) travelled all the way to Hawaii for the meeting of the International Society for Magnetic Resonance in Medicine.

A variety of themes

Another theme throughout the meeting was the work being done to enhance the specificity of commonly used MRI methods, for example in the ‘Recent advances in diffusion, perfusion and fMRI’ and ‘Chemical exchange saturation transfer (CEST) imaging’ educational sessions. Dan Gochberg (Vanderbilt University) emphasised that standard $T_1$ and $T_2$ weighted MRI methods are already sensitive to chemical exchange effects, and the added value of a CEST is only apparent if the specificity of the measured contrast can be elucidated.

Radiogenomics certainly seems to have potential as a strategy for making personalised treatment decisions

Olivier Gevaert (Stanford University) gave an excellent introduction to radiogenomics. This relatively nascent field correlates features automatically extracted from MRI images with genomic data obtained using, for example, DNA microarray analysis. Whilst still very much a research tool at the moment, radiogenomics certainly seems to have potential as a strategy for making personalised treatment decisions based on linking fundamental molecular biology to imaging phenotypes.

A variety of themes

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The theme of specificity is closely tied to quantitative MRI, which continued to be a popular topic this year. As well as the usual sessions covering technical and hardware developments to improve quantitative MRI measurements, two plenary sessions were also dedicated to the field. The Lauterbur lecture, given by Leon...
Axel (NYU Langone Medical Center), focused on quantitative measurements of cardiac function using MRI, and the NIBIB New Horizons lecture by Nicole Sieberlich (Case Western Reserve University) gave a fantastic account of how influential magnetic resonance fingerprinting has been in making quantitative MRI a clinical reality.

**Focus on new areas of research**

ISMRM has always been a clinically focussed meeting, so the inclusion of a ‘Preclinical tumour microenvironment imaging’ session this year was very welcome. Preclinical MRI is uniquely able to provide a fundamental biophysical understanding of MRI signals. An interesting example of this was the work by Dominguez-Viqueira *et al.*, who have developed a pipeline to register *in vivo* MRI and *ex vivo* immunohistochemistry imaging modalities to study tumour hypoxia. In addition, preclinical MRI can also demonstrate the translational potential of novel MRI methods, as shown by Little *et al.* in work looking at oxygen-induced changes in $T_1$ and $T_2^*$ in renal cancer xenografts and patients with renal carcinoma. There is always a huge amount of interesting and useful preclinical MRI work on display at ISMRM, although usually disparately distributed across the meeting, so it was great to see a session dedicated to it this year.

Machine learning made its way to the forefront of MRI research this year, with a call for late-breaking abstracts and a dedicated session on the topic. With talks on novel ways to reconstruct undersampled MRI data, automatically segment different tissue types, synthesise pseudo-CT images from MRI data and predict patient outcomes, machine learning certainly holds promise for the future in a wide range of research areas.

Other new additions to this year’s meeting were the Resonarium and the Secret Sessions. The Resonarium was a dedicated space in the Exhibition Hall, offering a laidback space to rest inbetween sessions and featuring dangerously comfortable armchairs! The Secret Sessions were pioneered by Karla Miller (University of Oxford) and featured several interesting panel discussions, including how to get more involved in ISMRM, career planning and turning ideas into concrete developments in MRI. I’m excited to see what next year’s Secret Sessions have in store for us, and they’re a great addition to the meeting.

The week concluded with Penny Gowland (University of Nottingham) giving the Mansfield lecture. She described how Peter Mansfield developed echo-planar imaging, including an anecdote of the ‘eureka’ moment striking Peter whilst waiting at traffic lights on his drive home, and how his determination inspired her career of imaging dynamic processes *in vivo*. In the same year as the MR community mourned the loss of Peter Mansfield, Penny’s talk was a fitting tribute to one of the founders of the field.

As usual, ISMRM was equal parts inspiring, invigorating and exhausting – and that’s saying nothing about the 20-hour journey home! I am immensely grateful to IPEM and the Prizes and Awards Advisory Group for their support.

**REFERENCES**


**AFFILIATION**

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Charitable work to use knowledge and skills

Maighread Ireland and Jessica Chiu completed a 6-week voluntary placement in North Mexico, using design and manufacturing skills to develop a sustainable communication mounting device.

Upon finishing the Scientist Training Programme as registered Rehabilitation Engineers, we sought an opportunity to utilise the knowledge and skills we had obtained over the last 3 years for a charitable purpose. We identified this need at the Instituto Nuevo Amanacer (INA) in Monterrey, North Mexico, which our background and skills could assist with.

INA is a charitable institute for children and young adults with cerebral palsy which brings together medical, educational and therapeutic services, such as postural management, physiotherapy and speech and language therapy, alongside recreational activities. The staff have created an institute which integrates these varied services to create a friendly, welcoming and sociable environment for children and their families.

A number of children at INA require communication aids, for which INA have been donated several tablet computers. Communication is vital for one’s independence and participation, which is paramount for a child’s development. Only a handful of these tablets were being used, and the remaining devices were stored in a cupboard. It was clear that there was an obstacle preventing the intended use of the tablets, and it became our work to find out why and resolve this.

Our design work started in the UK with the help of Paul Hewitt, an engineer based at the ACE Centre, Manchester, who has previously worked with INA. Paul put us into contact with staff at INA, and with their feedback and Paul’s input we were able to begin designing a solution.

We developed an initial prototype in the UK, which fully housed a tablet device and kept external cables out of reach. The casing also had the option of a key guard and speaker for individuals who required these. These types of cases are commonly used in the UK; however, they can cost significantly more than the tablets themselves. We had to ensure that our solution was low-cost to be feasible and sustainable within INA.

Our first impressions of INA were extremely positive – we were impressed at how well-resourced, in terms of services and equipment, they were. This is largely a result of the work carried out by a UK-based charity, MeDiCT (Mexican Disabled Children’s Trust). MeDiCT’s founder and occupational therapist Sarah Davies introduced and developed a sustainable postural management programme during the 2 years that she spent at INA from 1999. INA now has a fantastic postural management clinic and manufacturing workshop in their Centro de Atención Postural (CAP). MeDiCT continue their support by sending equipment, donated and refurbished by Specialised Orthotic Services (SOS) and MeDiCT volunteers to deliver training.

The staff have created an institute which integrates these varied services to create a friendly, welcoming and sociable environment.

We observed issues such as the users relying on therapists to hold the tablets during sessions, or them being insecurely velcroed or cable-tied to trays.

Designing the prototype

Following our observations and feedback, we designed a solution that was able to be easily manufactured in the workshop at INA. This was completed in two stages: firstly, the design stage and considerable feedback and testing, and secondly, the manufacturing of the final device.

The team at the Instituto Nuevo Amanacer
conversations, we developed a list of final requirements for the design which were:

- impact-resistant;
- adjustable view angle;
- securely positioned on a tray;
- option of a keyguard, which could easily be placed and removed;
- low-cost, and
- sustainable.

We worked with a local Monterrey company called Bioana to laser cut further prototypes. Bioana is a medical technology research and design company established by a trio of inspiring young female biomedical and clinical engineers. These prototypes were reviewed by staff during organised drop-in sessions, and from these we obtained vital feedback.

Final prototypes, named Capsulá (Spanish for capsule), were tested with the children that we had observed previously in our first week. We saw how the teachers, therapists and children interacted with the device, and were pleased with the outcome and the feedback received.

Capsulá was a success! Therapists reported that Capsulá had made their therapy sessions much easier, and children were getting seemingly less frustrated with the use of a key guard. Capsulá enabled the children to use the tablets independent of the therapist.

As a design project we were pleased that within 6 weeks we had developed several prototypes, finalised our design and successfully implemented this into clinical services. All of the materials and manufacturing were sourced either locally or within the institute.

Establishing these links was tricky at times, as we both spoke different languages and calculated dimensions in different units! Technical documentation was also completed, including manufacturing instructions to ensure the sustainability of Capsulá.

The design of Capsulá removes physical barriers faced when using the tablets as communication aids. We hope that the long-term implementation of Capsulá will increase and improve the function of the tablets as communication aids within INA.

Acknowledgements

We would like to thank Sarah Davies for facilitating this work and for her support throughout all stages of the project, and Paul Hewett and Peter Watt for their design and technical input. Thanks also to IPEM for their contribution of a trainee travel bursary to the project. Finally, thank you to all the staff at INA, especially those in the CAP workshop for their help and advice during our time at INA.

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MS JESSICA CHIU
Area of work is Rehabilitation Engineering with a special interest in device design
**ISMRM meeting report**

Marc Rea (Imperial College London Healthcare NHS Trust) would like to thank IPEM for their contribution towards his travel costs, which enabled his attendance at this meeting.

The International Society of Magnetic Resonance in Medicine (ISMRM) Annual Conference 2017 was held at the Honolulu Convention Centre, Hawaii, USA. The beachside location was obviously a big draw and with my shades and shorts packed I set off in hope that the conference sessions would live up to the huge billing and justify the exortionate registration fee.

**Day of CEST**

The meeting began on the Saturday; the weekend educational courses now being included as standard – something the society have used to justify the increased attendance fees. It was pleasing to see that some of the usual faces (and many new ones) had made the effort.

Conferences of this size offer a multitude of sessions, well suited to the variety of specialisms in MRI. I was particularly interested in cancer imaging and treatment planning, and so was at the first session on brain cancer. Near the end of the session, Ji Park (University of Ulsan College of Medicine, Seoul) presented an interesting talk on amide proton transfer (APT) imaging (figure 1), a subset of the CEST (chemical exchange saturation transfer) method, and I wondered about the prospects for molecular imaging and how it might be useful back home.

One of the joys of large conferences is the opportunity to learn, and I duly dived headfirst into all things CEST, seeing an opportunity to overcome some of the limitations of spectroscopy in quantifying metabolic concentrations.

**Every year at ISMRM there is a buzz around a topic which gets people excited and this year was no exception; deep-learning computing and artificial intelligence**

Another dedicated CEST session on the Sunday gave me a chance to grasp more of the terminology, techniques and innovations, and by the end of the day I was ready to get the conference started. An evening welcome party got underway, a chance to catch up with colleagues over a few pints and discuss the week ahead.

**RoboJob**

Every year at ISMRM there is a buzz around a topic which gets people excited and this year was no exception; the focus being on deep-learning computing, and specifically artificial intelligence (AI).

There is still much confusion over what AI might be capable of; speaking to various people I found a wide range of motivations for the perceived AI ‘buzz’, from genuine interest in improving methods to the commercial opportunism of replacing radiologists in diagnosing images. I heard strong opinions from the cynical to the hysterical, and the ubiquitous question, ‘When will my job be done by robots?’ (answer – sooner than you think!).

As expected, the two out of three AI sessions I attended were absolutely jam-packed with eager scientists hoping (or not) to hear about the end of their working life. Whilst I found most of the talks interesting, having some ICT experience allowed me to scrutinise which concepts are grounded in reality and/or feasible on clinical equipment. I found the work of Florian Knoll (NYU School of Medicine) to be a perfect illustration of all that is good in AI. His work at New York University demonstrated improvements in the efficiency and speed of compressed sensing (CS) reconstructions, a development which may finally

**FIGURE 1.** An APT map of the brain (left) in comparison with a post-contrast T1 image (right)
overcome the issues associated with both image quality and reconstruction time. Amazingly, this was done whilst training his neural network with random images from Google! It was easy to imagine further improvements using medical image sets for training, and it provides hope that AI may finally bring CS to the forefront of clinical MRI.

**Samba nights**
On Tuesday night, we attended the Siemens corporate party – a chance to meet the corporate side of the industry and leave your wallet at home! I had an interesting discussion with a Siemens executive around their recent dominance in the MRI market, and how (in her opinion) it was all down to usability and training rather than hardware advances.

After hearing some authentic Hawaiian live music, I teamed up with the usual culprits, including **Donald McRobbie** (University of Adelaide) and a couple of Brazilian researchers, and we decided to create a Brazilian Chapter of ISMRM, the first meeting of which was promptly held partially submerged on Waikiki Beach until the early hours.

**May I intervene?**
Interventional MRI has long been a focus for me, and I was buoyed by the large increase of interventional centres, and work reported at the interventional sessions. One presentation by **Pooja Gaur** (Stanford University) involved the removal of the water bath artefacts during brain FUS (MRgFUS: MR-guided focused ultrasound) treatments (figure 2). This was achieved by filtering and prior-segmentation of the phase images using a Log-Gabor filtering scheme, and being directly related to work at Imperial, it is something that could be taken back to incorporate in our department.

**Money in the bag**
The week drew to a close with the final reception on the Conference Centre roof, where Willie K, a famous ukulele player, sang us off. It seemed the Hawaiian vibe had rubbed off on the crowd and most of the delegates were feeling refreshed and ready to go back armed with their new knowledge (figure 3).

There was still time for one final hilarious episode which left **Greg Brown** (University of South Australia) red-faced, as it appeared he had inadvertently ‘stolen’ somebody’s rucksack. As Greg tried drunkenly to find the missing owner, we spotted some security guards panicking (and about to call in the SWAT team), and Karyn and I pieced together the two incidents. It turned out that the bag belonged to none other than ISMRM President Scott Reeder. Happily, it was all resolved over a final beer as we said Aloha to each other and this most beautiful paradise, and we were left wondering whether Greg will actually be allowed into the next meeting in Paris in 2018.

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MR imaging, ablative lasers and skin

Matthew Marzetti (Ninewells Hospital and Medical School, Dundee) reports on his recent project, conducted as part of the medical physics training scheme in Scotland.

MR imaging provides excellent contrast between soft tissues and is routinely used to assist in the diagnosis and monitoring of several clinical conditions. However, there is little published literature regarding dedicated imaging of the skin. Whilst MRI can provide high-resolution anatomical images, this resolution is generally in the order of millimetres. The purpose of my project – which I conducted within the framework of the medical physics training scheme in Scotland – was to develop an MRI protocol capable of acquiring images of the skin with a submillimetre in-plane resolution. These would need to be capable of visualising the different layers of the skin.

Phase 1: MR protocol development for high-resolution skin imaging

Imaging sequences were created to produce high-resolution images (up to 90 μm pixel size) using a small field-of-view (FoV) surface loop coil. This coil has excellent sensitivity over a small region, which is necessary as increasing the resolution of an MR image decreases the signal-to-noise ratio (SNR). All imaging was conducted on a 3T Siemens Prisma™ MRI scanner.

Example images are shown in figure 1. Each of these imaging sequences provides different contrast and highlights different layers of the skin. The epidermis (~0.2 mm thick), dermis (~1.5 mm thick) and subcutaneous fat (~1 cm thick) can each be seen clearly at least one sequence. These healthy volunteer images were reviewed by a consultant radiologist and judged to be of diagnostic quality.

Phase 2: high-resolution MR protocol – clinical application

Whilst large, invasive skin cancers may be imaged using MRI at 1.5T, the higher resolution and image quality of these sequences provides the opportunity to investigate other more subtle skin conditions. For example, a patient undergoing UVA phototherapy treatment for scleroderma was imaged at 3T using sequences from the developed protocol (figure 2).

Scleroderma is a rare condition that causes thickening of the skin and can restrict movement. T1- and T2-weighted spin echo and gradient echo sequences were acquired over the area of scleroderma-affected tissue and also over an adjacent area of healthy tissue. Although no increase in skin thickness could be measured (possibly due to disease improvement as the patient had completed a course of ultraviolet phototherapy), gradient echo imaging showed different signal intensities in the dermis and epidermis in the affected tissue relative to the healthy tissue. Differences were also seen between the signal intensities of the connective septa within the subcutaneous fat in fat-suppressed images (figure 2).

Phase 3: visualisation of skin laser ablation effects using high-resolution MRI

Finally, an investigation was conducted to determine whether clinical MRI could be employed to investigate the penetration depth achieved by ablative fractional skin lasers. Fractional lasers are used to treat the skin by dividing the main laser
beam into several microbeams. The holes burned into the skin by these lasers are generally in the order of 100 microns in depth. Each of these microbeams is incident on a microscopic area of skin for a short period of time. These lasers have a range of medical and cosmetic applications but if used incorrectly can cause scarring and permanent damage to skin. As a result, it is important to understand laser–tissue interactions. To investigate penetration depth of the laser, skin is usually excised and observed under a microscope. This technique can lead to distortions in the tissue and only provides information at a single time point, meaning longitudinal studies cannot be conducted. If successful, MRI imaging would address these limitations.

Gelatine- and water-based phantoms were created and irradiated by a fractional CO₂ laser. MR imaging results were highly dependent on the water content of the phantom. At a laser exposure of 200 ml/microbeam, hole depth increased from 107 μm for a 70 per cent water phantom to 233 μm for a 91 per cent water phantom. These holes were also observed on the skin of a healthy volunteer (figure 4) following laser ablation, and these are the first known in vivo MR images of ablative fractional laser effects on skin. This has the potential to be an extremely useful tool in the future for non-invasive investigation of fractionated laser interactions with tissue.

**Conclusion**

During this project, high-resolution clinical MR sequences for examination of the skin have been developed, which are capable of visualising disease-induced changes in the different layers of the skin and the ablative effects of fractional skin lasers. However, there are still a few limitations; notably, the slice thickness is considerably larger than the in-plane pixel size due to limitations associated with magnetic field gradient performance. Other experimental challenges have been experienced in relation to image acquisition time limitations, signal localisation and patient positioning. However, further MRI sequence optimisation and healthy volunteer work is planned to help with further learning in order to tackle these known difficulties.

**REFERENCES**


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Matthew Marzetti Department of Medical Physics, Ninewells Hospital and Medical School, Dundee
Europe’s biggest asset managers and resale agents reveal secret weapon: an engineering department!

The Hilditch Group is well known for the sale of medical assets, having founded the UK market 28 years ago. The company has developed its service to include a comprehensive range of activities directed at not just selling equipment but also managing assets, making it much more than just another auction house.

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Inventory evaluation
Hilditch’s engineers are also key to its asset management service, working closely with the company’s professional valuers and assisting hospitals to verify their equipment inventories. This may involve checking an entire department or hospital’s inventory to ensure that all items are accounted for, adding items that may be missing from the list, or deleting old redundant equipment.

The medical engineering team also evaluates the condition, age and remaining life of machines, enabling valuers to provide accurate Asset Transfer valuations. This service is increasingly being utilised by hospitals as they merge departments, or outsource services.

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Welcome to another bumper issue of Scope! In our ‘Just Published!’ section you will find some varied books recently published (or just about to be). These include Practical Radiobiology for Proton Therapy Planning, accommodating the current special focus issue on proton therapy. There is also the new title Quantum Leadership: Creating Sustainable Value in Health Care, emphasising the characteristics and role of the complex leader in the context of complex adaptive systems and responsive processes.

The New Reports section includes the usual list of links to medical physics newsletters from around the world. There are a number of consultations and also updates linked to the draft IR(ME)R 2018 regulations. Note that IRR 2017 was planned to be implemented from 1st January 2018.

As highlighted in the previous issue, we are in the process of moving to a new reviewer’s platform, which will also be used for all Scope activities. If you have requested to review a book, there may be some more delays in processing your request (apologies!). We are hopeful that the new platform will be set up in early 2018.

If you would like to review a book or have a comment on any part of the Scope magazine then please Tweet, email or send us a letter!

Don’t forget that reviewing counts towards your CPD (see ‘Self-directed learning’, HCPC Guidance to Standards for CPD – duties as a registrant). Moreover, reviewing a book means you also get to keep it.

Just Published!

Radiation Biology for Medical Physicists by C.S. Sareka and Christina Armplia (Taylor & Francis) is designed to convey as much information as possible in a concise and simple way to make it suitable for students, researchers and clinical medical physicists. Better meanings, codes and examples are included. Most of the basics are also covered for easy reference, along with a glossary of objective-type questions.

Classification in BioApps: Automation of Decision Making by Nilanjan Dey, Amira S. Ashour and Surekha Borra (Springer) highlights recent scientific research on artificial neural networks in biomedical applications, addressing the fundamentals of artificial neural networks, support vector machines and other advanced classifiers, as well as their design and optimisation.

Nuclear Medicine Physics: The Basics, 8th edition by Ramesh Chandra and Arman Rahnim (Lippincott Williams & Wilkins) helps build foundational knowledge of how and why things happen in the clinical environment. Ideal for board review and reference, the 8th edition provides a practical summary of this complex field, focusing on essential details as well as real-life examples taken from nuclear medicine practice.

Wearable Sensors: Applications, Design and Implementation by Subhas Mukhopadhyay (IoPP) is written for scientists, engineers and practitioners by an international collection of authors. This book reviews the fundamentals of wearable sensors, their function, design, fabrication and implementation. Their application and advanced aspects including interface electronics and signal processing for easy interpretation of data, data transmission, data networking, data security and privacy are also included.

Practical Radiobiology for Proton Therapy Planning by Bleddyn Jones (IoPP) covers the principles, advantages and potential pitfalls that occur in proton therapy, especially its radiobiological modelling applications. This book is intended to educate, inform and to stimulate further research questions. Additionally, it will help proton therapy centres when designing new treatments or when unintended errors or delays occur. The clear descriptions of useful equations for high LET particle beam applications, worked examples of many important clinical situations, and discussion of how proton therapy may be optimised are all important features of the text.

A Guide to Outcome Modeling In Radiotherapy and Oncology: Listening to the Data by Issam El Naqa (Taylor & Francis) explores outcome modelling in cancer from a data-centric perspective to enable a better understanding of complex treatment response, to guide the design of advanced clinical trials and to aid personalised patient care and improve quality of life. It contains coverage of the relevant data sources available for model construction (panomics), ranging from clinical or pre-clinical resources to basic patient and treatment characteristics, medical imaging (radiomics) and molecular biological markers such as those involved in genomics, proteomics and metabolomics.

Person-Centred Healthcare Research by Brendan McCornack, Sandra van Dulmen, Hilde Eide, Kirsti Skovdahl and Tom Eide (Wiley) provides an innovative and novel approach to exploring a range of research designs and methodological approaches aimed at investigating person-centred healthcare practice within and across healthcare disciplines. With contributions from internationally renowned experts in the field, this engaging resource challenges existing R&D methodologies and their relevance to advancing person-centred knowledge generation, dissemination, translation, implementation and use.

Quantum Leadership: Creating Sustainable Value in Health Care, 5th edition by Tim Porter-O’Grady and Kathy Malloch (Jones & Bartlett Learning) provides students with a solid overview and understanding of leadership in today’s complex healthcare delivery system. The 5th edition discusses leadership within the context of a new understanding of complex adaptive systems and complex responsive processes. Rather than focus on the mechanics of operations and function, this text emphasises the characteristics and role of the complex leader through both describing the context of complexity and the application of the role as a leader of these complex systems.

How to Complete a PhD in the Medical and Clinical Sciences by Ashton Barnett-Vanes and Rachel Allen (Wiley) provides a fresh insight into the PhD process and a concise framework to aid current and prospective students undertaking research in the medical and clinical sciences. Filled with useful hints, tips and practical guidance, the book covers key topics such as publishing and presenting, core principles and techniques in medical science, dealing with common pitfalls and how to write up and move on.
Reviews of textbooks published on medical physics, along with recently published books

**BOOK REVIEWS**

Why Hospitals Fail Between Theory and Practice by Parasad Godbole, Derek Burke and Jill Aylott (Springer) explores the current wider political, social and economic context of hospitals in the public and private sector globally and identifies the push and pull tension between the demands of the quality regulator and the requirements of healthcare commissioning processes. This book draws on the evidence of what works to improve the quality of hospital services in the development of medical and clinical leadership models. The book seeks to develop a specific paradigm shift in understanding the development of medical leaders by promoting a culture of engagement through participation and one that is defined by the experiences of medical leaders.

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