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It hardly seems credible that a year has passed since I sat down, full of trepidation, to write my first Scope column as IPEM President. In that column I promised that 2014 would be a year of fresh challenges and opportunities, a prediction that has come true not because of any great prescience on my part, but with a certain inevitability given the ever-changing environment in which we work. The end of my first year in office is a good opportunity to reflect on how much has been achieved, something that is easy to overlook in the midst of day-to-day busyness.

**Supporting innovation**

Delivery of final assessments for the first cohort of STP trainees was an enormous piece of work by IPEM members, working with the National School of Healthcare Science. At the same time, working with the Royal College of Radiologists and the Royal College of Surgeons, we developed curricula for Higher Specialist Scientific Training (HSST) in medical physics and clinical biomedical engineering, again to a very tight timescale, and the first HSST recruits are now in place. Our Workforce Intelligence Unit provided very timely and well-received advice on the implementation of new employment codes for healthcare scientists, and continues its work of mapping services and workforce to provide more robust data which, for example, will inform the commissioning of training places. Alongside this, our usual programme of one- and two-day conferences has continued to provide CPD opportunities for members across our full range of specialisms, and there have been promising discussions with colleagues in academia and industry as to how we might better meet the needs of these sectors and so widen our membership, facilitated by new membership rules agreed by the Board of Trustees in April. One aspect of this agenda is the development of new frameworks for accreditation of degree programmes and training courses, beginning with the MSc framework that has already been launched, and discussions are ongoing particularly with other engineering institutions regarding more joined-up approaches to this.

Outside the workforce and training arena, we have continued to support innovation, doubling our funding for pilot projects to £100,000 this year. We have also improved our engagement with the public, with over 50 outreach events supported by 150 IPEM members, including our first ever public lecture at Fairmount House, delivered by past president Professor Peter Wells. Professor Wells was also selected for the Science Council’s list of the top 100 practicing UK scientists, sharing this honour with three other IPEM members; this punching above our weight reflects and recognises the importance of our disciplines to wider society.

In the wake of the Scottish independence referendum, it is perhaps worth reiterating that IPEM is very much a ‘four countries’ organisation, with strong and active membership in all parts of the UK. Colleagues who attended the annual dinner in Glasgow in September were regaled with tales of my visits to Scotland during 2014, attending IPEM conferences, meeting members in their workplaces and taking part in degree examinations. My appearance with Professor Colin Gibson before the Health and Social Affairs Committee of the Welsh Assembly further reinforced for me the increasing divergence of healthcare policy across the UK, albeit in response to the same socioeconomic pressures. I believe that IPEM has responded well to this development, adapting structures as necessary and ensuring that all parts of the UK are represented among our senior officers and committees.

Whilst we reflect on the successes of the past year we do not rest on our laurels, and we already have a busy agenda for next year. We hope to submit a proposal for accreditation of the Register for Clinical Technologists (previously the VRCT) by the end of the year, and to achieve accreditation during the first half of 2015. As HSST and new arrangements for medical physics expert training bed down, we will need to ensure that appropriate and proportionate equivalence and grandparenting arrangements are in place to meet the needs of the existing workforce. Alongside this, work will continue on the Improving Clinical Engineering and Physical Science Services (iCEPSS) project, due to be piloted early in the new year, and associated work to develop a British Standard for Physical Sciences and Engineering Services in Healthcare. And perhaps the biggest challenge of all remains maintaining our volunteer effort in the face of increasing pressures on members in their day jobs.

As we look ahead to 2015, which at the risk of repeating myself promises to be another year of fresh challenges and opportunities, I wish all IPEM members and their families a well-deserved period of rest and refreshment over Christmas and the new year.
By the time you read this, the 2014 review of key elements of IPEM’s strategy will be drawing to a close. But there is still time to contribute your views and make your voice heard in future planning. The review focuses on the areas highlighted as concerns in responses to the 2013 member survey. There were four issues that threw up interesting, challenging or even contradictory results in the survey: regional structures, volunteering, policy work and public engagement.

Regional structures and volunteering
Take IPEM’s regional structures. Seventy-six per cent of respondents said they ‘rarely’ attended a regional meeting; yet 51 per cent said that regional meetings were one of the reasons they had joined IPEM initially, and 75 per cent said regional meetings were one of the reasons they remained a member. Sixty per cent felt it was important for IPEM to provide regional meetings. But only just over a quarter think regional meetings are done well at the moment; 15 per cent think they are poor and another quarter chose the middle ranking. So should we invest in the success of regional meetings, or have they been superseded by virtual networking opportunities? Do members still value face-to-face networking and learning opportunities at regional level, or are national meetings the way to go?

Volunteering was another contentious issue. In the survey, 25 per cent of respondents said they currently do volunteer work for IPEM, e.g. sitting on a committee, authoring a report or giving outreach talks. But 75 per cent said they don’t currently do anything for IPEM; and 77 per cent said they would not volunteer to help IPEM implement any changes. Of those saying they could not help, 35 per cent cited reasons other than lack of time or experience, including lack of guidance, difficult appointment route to committee positions, lack of confidence, ‘closed doors at IPEM’ and ‘negative impact on my work’. There are some big questions to explore here. Can a membership organisation function with less than 25 per cent of its members prepared to contribute? What more can we do to help those who would like to assist, but don’t? How do we unlock those ‘closed doors’?

Policy work and public engagement
IPEM’s work to influence policy by interaction with Parliament and policy groups is clearly important. In fact, 60 per cent of respondents felt policy work was very important; only 3 per cent felt it was not important. However, more than half could not rate how good this work was, implying they had no knowledge or experience of it. Of those who did rate it, just over a third thought it was good, a third were neutral and just over a quarter thought it was poor. To address the lack of awareness that these responses highlighted, from March next year there will be a regular page in Scope reporting on IPEM members’ policy activities. But in addition we will need members’ expertise to develop the positions we should take on key issues.

The last big area for the strategy review is public engagement. In responses to the survey, only 38 per cent of people indicated support for IPEM’s strategic objective to ‘build two-way engagement with public and patients’. Yet 48 per cent were in favour of raising IPEM’s profile with the public, making it one of the six best-supported changes proposed. By contrast, outreach to the general public was amongst the most poorly rated of IPEM’s activities. With recruitment underway to IPEM’s Public Engagement Panel, we need to understand more of members’ concerns about this area of its strategic work.
seasonal greetings to all! Over the course of this year, readers have contributed to several interesting Scope features, detailed meeting reports and useful book reviews. Moreover, members have taken the time to fill out the online Scope survey for which we have had a fantastic response. I would therefore like to thank you for all your contributions. I am hopeful that more members will be able to contribute to Scope in the future!

As you are aware, Angela Cotton, the Meeting Reports Editor, recently completed her handover to Kirsten Hughes. Angela has now stepped down from her role after years of voluntary service. She has been a great asset to Scope and will be deeply missed. Sadly, Frances Rye has decided to step down from her editorial role. She was involved with the initial setup of the Clinical Technologist section, which has been running for around 2 years. I wish both Fran and Angela the best for the future.

The change in the editorial team has created an exciting vacancy for a Clinical Technologist Editor, who will co-ordinate the section’s activities and work alongside Trevor Williams and David Stange. If you are an enthusiastic clinical technologist and would like to volunteer your services to the IPEM Scope magazine then I would be delighted to hear from you!

Ever wondered how the Scope name came about? This was something I have been wondering. So, with the help of Marie from the IPEM office, I was able to find the answer. In the March 1992 Scope issue, the title of the magazine was changed from HPA Bulletin to Scope as a result of a widening of its scope. As it goes, ‘the new title was chosen after deep consideration in the Publications Committee (recently renamed to “Journals Committee”) and elsewhere’. In the issue, the definition of Scope was also highlighted – ‘opportunity for exercising faculties and it is short for a number of instruments familiar to physical scientists such as oscilloscope, microscope, fluoroscope, etc.’. I do hope that Scope keeps meeting your needs!

Recently trending has been the moving story of Ashya King – a 5-year-old with a brain tumour (medulloblastoma) whose parents were battling for access to proton treatment under the NHS. Consequently, Professor Stuart Green co-authored a short educational article on proton radiotherapy highlighting some of the inherent issues. For those working in radiotherapy, in the three-part article by the IPEM Extended Hours Working Party highlights the issues around service provision. Alison Vinnall writes about the manufacturers’ perspective, whilst Graham Chalmers presents the results of the survey – the aim was to determine how much non-clinical time was required to support a safe clinical radiotherapy service. In the last part, Gill Lawrence discusses the challenges for the medical physics service.

Those wanting to get their teeth into fiction writing will find ‘Crossing the great divide’, written by Stanley Salmons, very handy indeed! Our editorial team has once again produced an exciting mix of journal club and technologist news, travel reports and book reviews – which I hope you find interesting. Happy 2015!

The title of the magazine was changed as a result of its widening of scope.

USMAN I. LULA EDITOR-IN-CHIEF
Critical appraisal was performed using the McMaster University instrument. This is a generic critical appraisal instrument relevant to any quantitative study. A purpose-built analytical instrument was constructed for the review, seeking details on the processes of conducting the journal club and how the effectiveness of the journal club had been evaluated.

In total, 101 articles were identified, of which 21 comprised the body of evidence. Of these, 12 described journal club effectiveness with methodological quality being moderate. Over 80 per cent of papers reported that journal club intervention was effective in improving knowledge and critical appraisal skills. The most frequent improvement sought from journal club intervention was in knowledge of biostatistics and/or epidemiology, or critical appraisal skills. Please refer to table 1 for outcomes reported from the comparative studies and table 2 for the elements of outcome measures.

Most articles mentioned that journal clubs were conducted monthly and noted that if conducted too often it diminished participant interest in attending. Informal sessions with food provision impacted significantly on attendance rates. Participant preparation appeared to be a key factor to facilitate healthy and meaningful discussion during journal club sessions. Article selection and its relevance to the attendees would appear to be a key element of a successful journal club in order to improve reading and critical appraisal skills and knowledge, and to encourage knowledge uptake to improve patient care.

Characteristics of successful journal clubs include regular and anticipated meetings; clear long- and short-term purpose; appropriate meeting timing and incentives; a trained journal club leader to choose papers and lead discussion; circulating papers prior to the meeting; using the internet for wider dissemination and data storage; using established critical appraisal processes, and summarising journal club findings.

### TABLE 1

<table>
<thead>
<tr>
<th>Criteria for analysis</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linzer (1987)</td>
<td>Sig Perceived reading habits of JC members significantly improved, with increased number of articles read/month</td>
</tr>
<tr>
<td>Linzer (1988)</td>
<td>Sig 86% of JC reported improved reading behaviour and 80% reported improved ability to critically read</td>
</tr>
<tr>
<td>Seelig (1991)</td>
<td>Sig Improved ability to appraise original research articles critically (p = 0.01), improved critical appraisal knowledge (p = 0.02)</td>
</tr>
<tr>
<td>Langkamp (1992)</td>
<td>Non-sig No significant change in any educational outcomes</td>
</tr>
<tr>
<td>Burstein (1996)</td>
<td>Sig Overall satisfaction p = 0.04, critical appraisal skills p = 0.22, clinical education p = 0.05</td>
</tr>
<tr>
<td>Spillane (1998)</td>
<td>Sig 22/28 respondents rated good to very good for review of recent surgical literature, 26/28 rated good to excellent on developing critical appraisal skills. All reported good to excellent at achieving a convivial social forum</td>
</tr>
<tr>
<td>Bazarian (1999)</td>
<td>No statistical reporting</td>
</tr>
<tr>
<td>Khan (1999)</td>
<td>Sig Reading time improved from 2.0 hours to 3.5 hours (p = 0.026) and knowledge and critical appraisal scores improved from 50.8 to 62.9 (p = 0.003)</td>
</tr>
<tr>
<td>Lattarier (2000)</td>
<td>Sig 85% of participants expressed interest in continuing the format without a major change</td>
</tr>
<tr>
<td>MacRae (2004)</td>
<td>Sig Participants performed better in test of critical appraisal skills than control group (mean score 58%/ +/- 8 vs 50%/ +/- 8) with a large effect size of 1.06 SD units</td>
</tr>
<tr>
<td>Struck (2005)</td>
<td>Sig Comparing pre-post knowledge test scores showed improvement (p &lt;0.001). On self-report, 50% agreed or strongly agreed that journal club experience assisted them in improving clinical skills</td>
</tr>
<tr>
<td>Muharjee (2006)</td>
<td>Sig The largest changes were seen in those with the least initial experience of reading and appraising qualitative papers. A significant level of change in confidence was noted (p = 0.012)</td>
</tr>
<tr>
<td>Assessment instrument</td>
<td>Elements being assessed</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Validity</td>
<td>Reliability</td>
</tr>
<tr>
<td>Linzer (1987)</td>
<td>✓</td>
</tr>
<tr>
<td>Linzer (1988)</td>
<td>✓</td>
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<tr>
<td>Seelig (1991)</td>
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<tr>
<td>Langkamp (1992)</td>
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<td>Burstein (1996)</td>
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<td>Spillane (1996)</td>
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<td>Bazarian (1999)</td>
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<tr>
<td>Khan (1999)</td>
<td>✓</td>
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<tr>
<td>Letterie (2000)</td>
<td>✓</td>
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<tr>
<td>MacRae (2004)</td>
<td>✓</td>
</tr>
<tr>
<td>Struck (2005)</td>
<td>✓</td>
</tr>
<tr>
<td>Mulkernierse (2006)</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 2: Elements of outcome measures

cost-effective way of enhancing practitioner capability. They highlight that one way in which practice behaviours should develop is from the continuous appraisal of them.

In the commentary provided by Matthews' on a review of whether or not journal clubs support evidence-based decision making, there were two key messages. The first was that to ensure success of a journal club, the format must be tailored to the educational needs of the learner. The second was that whilst there was no ideal format for a journal club, there are components that contribute to its effectiveness in changing behaviour (e.g. mentoring, didactic support, use of structures review instruments, adhering to the principles of adult learning). Adhering to the principles of adult learning theory is also supported by Hartzell et al. Nonetheless, the traditional approach of journal clubs does tend to have its own limitations. They tend to focus excessively on critical appraisal and in a controlled trial, a case-based journal club showed no difference between intervention and control in their ability to critically appraise a fabricated paper with methodological flaws. Perhaps the greatest limitation of a traditional journal club is that this format encourages participants to see evidence-based medicine as a separate exercise that is not integrated into daily patient care.

Navinah Nundill leads the journal club at the Medical Physics Department, University Hospitals Birmingham (UHB) and is supported by principal clinical scientists. She is a clinical scientist based in the Clinical Computing and Imaging Support Service (CCISS). The primary purpose of the club is to critically evaluate articles in the literature. Articles are selected based on how they would improve clinical practice in the department. There is a critique after presenting each article. The frequency of the journal club is fortnightly, lasting a period of an hour where 3–4 articles are presented. There is a list of agreed topics for each session from which articles are selected. Copies of the articles and presentations are stored in a common folder accessible by all staff members. A shared calendar in Microsoft Outlook is used to send reminders to staff who are presenting and for everyone attending the session. We are now envisaging that there should be a debate format in some sessions, and also a review of evidence that could benefit clinical practice in the department. The intention is to have a journal club that tries to meet the needs of all participants. We are now changing the format of our journal club so that article(s) from the latest issue of selected journals are presented. The aim is to ensure we are keeping track of the very latest developments in the field.

For readers who may be interested in performing a literature search, there is a useful guidance paper written by Krupski et al.6 Moreover, local libraries (e.g. NHS hospitals) can also be an excellent resource in assisting with searches. I recently attended a course at the UHB library on ‘Finding and using evidence for practice and research’ and felt that this can really help with improving research skills. This is one of many courses provided by the local NHS library. I am now looking forward to attending the next course on ‘Critical appraisal skills’.

Any comments? Email: Usman.Lula@uhb.nhs.uk

REFERENCES


Tables kindly supplied by Professor Karen Grimmer PhD, Professor of Allied Health, Director, International Centre for Allied Health Evidence, University of South Australia, City East Campus, North Tce, GPO Box 2471, Adelaide 5000. © 2008 Blackwell Publishing Ltd. How to run an effective journal club: a systematic review. J Eval Clin Pract 2008; 14: 898–911.
evaluation of the RayStation treatment planning system: modelling and calculation accuracy

The accuracy of the dose calculation in the treatment planning system (TPS) is strongly influenced by the TPS’s beam model accuracy. This requires critical validation of the dose computation algorithm. RayStation TPS has some advanced features to tackle modern-day challenges and complex demands.

At present, a rigorous dosimetry accuracy evaluation for the basic RayStation TPS has not been reported in the literature. This study aims to provide insight into the modelling process and to allow the basic dose calculation accuracy and clinical plan quality evaluation of this TPS. Outside the scope of this report are the more advanced features, e.g. deformable registration, fallback planning, multicriteria optimisation (MCO), dose tracking and adaptive replanning.

Dose evaluation tools including some of the latest software, phantoms and dosimetry equipment were used in this work (e.g. ArcCHECK device, 3DVH, Lucy stereotactic phantom, CIRS dynamic thorax phantom). Special attention was taken on the tolerances used, and these varied with increasing geometrical complexity and application of more complex algorithms or optimisation as required. Inherent limitations of the collapsed cone convolution algorithm superposition (CCC)-based calculations were taken into account.

To rigorously test the performance of the models, tighter tolerances were used for complex geometries and several publications were consulted in devising the commissioning tests and acceptance criteria (e.g. AAPM TG53 and IPEM Report 68). The Pinnacle TPS (v9.2) used for comparison in this work was previously commissioned for clinical use based on similar rigorous tests and tolerances. Beam modelling was based on guidance by RaySearch and was performed in RayPhysics, the physics modelling module of the TPS (v3.5). See figure 1 for details.

Modelling and validation for the Elekta MLCi and Agility beam models resulted in a good match to treatment machine-measured data-based tolerances of 3 per cent for in-field and out-of-field regions, 10 per cent for build-up and penumbral regions and a gamma 2 per cent/2 mm dose/distance acceptance criteria. TPS commissioning using a wide range of appropriately selected dosimetry equipment, and following published guidelines, established the MLC modelling and dose calculation accuracy to be within standard tolerances for.

CT AEC Phantom
A Computed Tomography Automatic Exposure Control Phantom, used for constancy testing of CT AEC systems.

Accu-Gold+
The next generation X-ray multimeter with new Accu-Gold+ ion chamber and solid-state multi-sensors. For use in Radiography, Fluoroscopy, CT, Dental, Mammography and Survey.
all tests performed. In both homogeneous and heterogeneous mediums, central axis calculations agreed with measurements to within 2 per cent for open fields, 3 per cent for wedged fields and 4 per cent off-axis. Treatment plan comparisons for identical clinical goals were made to Pinnacle for the following complex clinical cases: hypofractionated non-small cell lung carcinoma, head and neck, stereotactic spine, as well as for several standard clinical cases comprising of prostate, brain and breast plans. DVHs, target and critical organ-at-risk (OAR) doses as well as measured point doses and gamma indices for these composite plans were assessed. For all 32 cases, the patient QA checks showed >95 per cent of pixels passing 3 per cent global/3 mm gamma. Refer to tables 1 and 2.

A systematic beam modelling process and rigorous dosimetric evaluation, applying sensitive dose metrics, suitably chosen measurement systems and tighter tolerances have been applied to the RayStation TPS. Equivalent plan quality to Pinnacle has been attained, whilst point-dose differences, gamma indices and 3D dose correlations to 3DHW showed no noticeable systematic dosimetric errors. RayStation TPS has been tested in challenging geometries, as well as in some complex clinical applications, and its overall performance has been found to be satisfactory.

FIGURE 1

PDDs – beyond d\text{max} – photon energy spectrum

PDDs – build-up region – electron contamination

Profiles – off-axis softening – flattening filter effect

Profiles – beam profile corrections – radial fluence scaling

Penumbra small fields – steepness – primary photon source width

Penumbra larger fields – shoulder, heel, tails – flattening filter source

Field size dependence – output factor corrections and flattening filter source

Collimators – offset, gain and curvature

MLCs – leaf tip, tongue and groove – square root of MLC transmission

Wedge – material factor, wedge scatter source, wedge transmission

Wedge – wedge output factor corrections

Figure 1: Summary of the iterative beam modelling steps followed to match the TPS beam models to the measured data

MORE INFORMATION

The work was published in J Appl Clin Med Phys 2014; 15(5). doi:10.1120/jacmp.v15i5.4787

NEWS EDITOR’S COMMENT:

This is a helpful paper for those who are aiming to commission the basic RayStation TPS components. It highlights coverage of several important aspects, i.e.:

- modelling steps and validation for percentage depth doses, profiles and associated penumbra regions, MLCs and wedges;
- point dose measurements for central axis and off-axis open and wedged fields, extended and oblique distances using homogeneous and inhomogeneous media;
- MLC transmission, tongue-and-groove modelling accuracy and source size checks using picket, garden fence, strip pattern and fingers film tests;
- analysis of 32 clinical test plans covering 3D conformal, forward- and inverse-planned IMRT and VMAT. Plan quality tools included comparison of 3D dose grid and dose-volume histograms. Fluence map/gamma were analysed using a 3D cylindrical phantom and associated software (3 per cent/3 mm and 2 per cent/2 mm with 10 per cent threshold).

There is a wealth of information to be gained from publishing commissioning experiences. It also allows one to plan a programme of commissioning with better insight, providing potential solutions and problem areas. Most importantly, it can form part of an evaluation process when considering a TPS replacement programme.

The corresponding author Bon Mzenda stated in private communications (September 2014) that his team at Auckland Radiation Oncology (ARO) are currently working on projects in deformable image registration, radiobiological plan optimisation techniques, scripting of plan complexity metrics as well as investigating adaptive replanning accuracy. They are also validating the electron Monte dose computation as well as working on the clinical implementation of MCO.

As of writing, the latest version of RayStation was v4.5. This update provides potential improvements to issues inherent in v3.5 of RayStation TPS. RayStation whitepapers can be found on the RaySearch website (under Publications). Refer to the following link for more details on v4.5 features: http://www.raysearchlabs.com/en/RayStation/RayStation-45-News/

For followers looking to accept and commission a new TPS, the work presented here provides some useful sources of guidance. Other reports that may be of interest to you are:


There is an excellent thesis by Andrew Thinnes McVickers from Duke University (USA) on ‘Clinical implications of AAA commissioning factors and ability of common commissioning and credentialing procedures to detect them’. This work assessed the impact of introducing dosimetric and geometric errors into the TPS commissioning process. It shows that guidance documents (in this case, AAPM TG-119: IMRT Commissioning Tests, 2009) are effective at detecting errors (http://dukespace.lib.duke.edu/dspace/handle/10161/8859).

If you have a comment on this news article, or would like to share your experiences with the medical physics community, then please get in touch with me via email: Usman.Lula@uhb.nhs.uk

BY USMAN I. LULA AND RICHARD AMOS

If you have a comment on this news article, or would like to share your experiences with the medical physics community, then please get in touch with me via email: Usman.Lula@uhb.nhs.uk
**JOURNAL CLUB NEWS** BY USMAN I. LULA AND RICHARD AMOS

### RANDOM METASTASIS
The spreading of a cancerous tumour from one part of the body to another may occur through pure chance instead of key genetic mutations, a new study has shown. Researchers used a model to show that metastasis could just as likely derive from common cancer cells circulating in the bloodstream (Phys Biol 11: 046003).

### INTERACTIVE PLANNING
An interactive treatment planning platform has been developed permitting real-time manipulation of dose distributions including DVHs and other dose metrics. With real-time interactive planning trade-offs between the target and organ-at-risk may be evaluated efficiently, providing a better understanding of the dosimetric options available to each patient in static or adaptive radiotherapy (Phys Med Biol 59: 4845).

### DOSE CALCULATIONS
To speed up the absorbed dose computation whilst accounting for tissue heterogeneities, a collapsed cone (CC) superposition algorithm was developed and validated for $^{90}$Y. Our results show that the CC superposition is a very promising alternative to MC for $^{90}$Y dosimetry, whilst significantly reducing computation time (Phys Med Biol 59: 4769).

### QUADRAPEUTICS
Nanoscopic explosions triggered by a laser can enhance the effectiveness of traditional cancer therapies by 10 to 100 times, according to scientists in the US who are pioneering the technique. ‘Quadrapeutics’ appears to kill cancer cells whilst leaving healthy cells intact, and could prove especially good at targeting drug-resistant tumours and those in children (Nat Med 20: 778).

---

#### Table 1: Summary of average percentage difference and standard deviation ($\pm$ 2 SD) from curve quality metrics for (a) PDDs, (b) cross-plane profiles and (c) in-plane profiles (averaged over all depths (i.e. $D_{max}$: 5, 10, 15, 20 and 25 cm deep) for square field sizes from 1 x 1 cm to 40 x 40 cm, all at SSD of 100 cm)

<table>
<thead>
<tr>
<th>Medium</th>
<th>Test</th>
<th>Depth</th>
<th>Range of difference (%)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous (water &amp; plastic phantoms)</td>
<td>Open central axis point doses</td>
<td>5 cm</td>
<td>1.6% to 5.0%</td>
<td>0.1% to 0.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 cm</td>
<td>1.9% to 5.5%</td>
<td>0.1% to 1.0%</td>
</tr>
<tr>
<td></td>
<td>W10</td>
<td>5 cm</td>
<td>1.2% to 5.8%</td>
<td>0.1% to 0.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 cm</td>
<td>1.6% to 6.8%</td>
<td>0.1% to 1.0%</td>
</tr>
<tr>
<td></td>
<td>W25</td>
<td>5 cm</td>
<td>1.0% to 6.0%</td>
<td>0.1% to 1.0%</td>
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<td></td>
<td></td>
<td>10 cm</td>
<td>1.4% to 7.0%</td>
<td>0.1% to 1.0%</td>
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<tr>
<td></td>
<td>Homogeneous (water &amp; plastic phantoms)</td>
<td>Open central axis point doses</td>
<td>5 cm</td>
<td>1.6% to 5.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 cm</td>
<td>1.9% to 5.5%</td>
<td>0.1% to 1.0%</td>
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<tr>
<td></td>
<td></td>
<td>15 cm</td>
<td>2.3% to 6.0%</td>
<td>0.1% to 1.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 cm</td>
<td>2.7% to 6.5%</td>
<td>0.1% to 1.0%</td>
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<td></td>
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<td>25 cm</td>
<td>3.1% to 7.0%</td>
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<td>Wedged central axis point doses (W15,W20,W45,W60)</td>
<td>5 cm</td>
<td>1.6% to 5.0%</td>
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<td>10 cm</td>
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<td>Homogeneous (water &amp; plastic phantoms)</td>
<td>Extended SSD 60 cm</td>
<td>5 cm</td>
<td>1.7% to 4.0%</td>
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<td></td>
<td>Homogeneous (water &amp; plastic phantoms)</td>
<td>Uniform phantom</td>
<td>4x4 cm</td>
<td>1.2% to 2.0%</td>
</tr>
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</table>

All figures and tables kindly supplied by Bongile Mzenda, Auckland Radiation Oncology, Auckland, New Zealand: Department of Medical Physics, © Bongile Mzenda, Koki V. Mugabe, Rick Sims, Guy Godwin and Dayan Loria. Modelling and dosimetric performance evaluation of the RayStation treatment planning system. J Appl Clin Med Phys 2014; 15(5)

#### Table 2: Variation of point doses in inhomogeneous medium, RayStation vs measured, showing maximum to minimum differences for checks performed at 5, 10 and 20 cm depths for open and wedged fields, for field sizes ranging from 1 x 1 cm to 40 x 40 cm (unless stated otherwise)

*Note: Tolerance ±10%, field size ±2%, in-field ±3%, penumbra ±10%, out-of-field ±5%*
Proton radiotherapy: hype, fiction and a few facts...

Stuart Green and Paul Sanghera (University Hospital Birmingham) weigh up the advantages and disadvantages of this treatment

Proton beam therapy (or our preferred title of proton radiotherapy) is a form of radiotherapy delivered with beams of high-energy protons rather than the more usual beams of high-energy x-rays (or less frequently beams of electrons). It is part of the general field of particle radiotherapy that includes the use of particles that are heavier than protons. Beams of carbon ions are the main topic for clinical research around the world, although there is also interest in other particles such as helium ions.

Radiotherapy involves the delivery of very large radiation doses to tumours with the aim of ensuring that none of the cancer cells in the tumour are able to go on reproducing after the treatment.

The main potential advantage of proton radiotherapy comes from the basic physics of proton interactions and the generation of what is termed a ‘Bragg peak’. Energy is deposited at a relatively low rate in the entrance path of the beam, and rises to a maximum at depth. The position of this maximum can be varied to match the depth of a tumour, and beyond this depth, no dose is delivered. This is quite different from the physics of x-ray interactions which follow a more continuous deposition of dose, being higher in the entrance region and reducing gradually with depth into the patient. Actual treatments often involve beams delivered from many angles, all converging on the identified tumour.

This suggests that proton therapy represents a dramatic and substantial improvement on x-ray radiotherapy for many patients. This is not always correct, however, as modern x-ray techniques such as intensity-modulated radiotherapy (IMRT) can do an excellent job of shaping dose distributions, and so detailed treatment planning studies and clinical evaluations are required to understand what benefit proton therapy might deliver. In addition, certain technical aspects, such as image guidance to target treatment, may not be as advanced in some proton centres when compared to modern IMRT departments. The area of least debate is in the treatment of some children with cancer.

Effects of radiobiological doses

An issue which is variously discussed, worried about and ignored is the radiobiological effect of the dose delivered by beams of protons. It is well established in tissue culture biological studies that the biological effect of a proton beam is higher towards the end of the range, by perhaps 40–50 per cent, than it is in the beam entrance region. In a clinical situation, where proton energies are modulated to deliver a uniform dose to a target, this effect blurs out somewhat and it has been clinical practice to use a single relative biological effectiveness of 1.1 applied throughout the dose distribution. Opinions are split on this issue in the proton radiotherapy community, with two main viewpoints which can be characterised as:

1. Those who believe that there are no major differences in the radiobiological issues faced by the proton and the x-ray radiotherapy communities. One of the important issues to be understood by both communities relates to steep dose gradients and the ability to partially...
irradiate healthy tissues. Understanding the biological effect and the radiation tolerance of tissues in this situation requires detailed understanding of complex dose–volume relationships which differ greatly between tissues. Modern x-ray IMRT has a similar ability to proton radiotherapy to generate steep dose gradients, so overall in this respect the challenges are similar (noting of course that scanned proton treatments have markedly different dose-bath characteristics which can have important biological consequences).

2. Those who believe that proton radiobiological effects are insufficiently well characterised across the breadth of important healthy tissues, and that this lack of understanding could lead to incorrect clinical decisions being made. Such decisions could be related to the dose distribution applied to a particular clinical situation, or even to whether proton radiotherapy should be selected at all for a patient. Holders of these views tend to believe that further understanding could be gained from a programme of animal radiobiology experiments. In the case of medulloblastoma there are a number of recent articles exploring the issues and indicating cause for some caution.1,2,3

It is hard to tell whether those in the first camp are there because they have fully engaged with this issue and made a considered decision, or whether they have only minimally engaged. As authors we are probably in a third (undecided) camp. It adds weight to the issue to appreciate that with the proton beam arrangements and planning margins typically used, the area of highest and most uncertain biological effect (the proton distal edge) will most usually be in healthy tissue bordering the clinical target.

Understanding the technology
Another issue of great debate relates to the technology of particle therapy. It is often surprising to newcomers in the field to find such a multitude of suppliers, far more than in x-ray radiotherapy. Until recently, the proton community was divided between the ‘synchrotron’ and ‘cyclotron’ advocates. This debate has now been joined by newer, more compact accelerator approaches; a variety of gantry designs including gantries which carry the entire accelerator. Scanned beam technologies are becoming the accepted future path for particle therapy, but issues of scanning speed, speed of energy variation and spot size mean there are many choices to be made. The newer technologies are not yet fully established in the marketplace and both clinical experience and data on the entire accelerator. Scanned beam technologies are all for a patient. Holders of these views tend to believe that further understanding could be gained from a programme of animal radiobiology experiments. In the case of medulloblastoma there are a number of recent articles exploring the issues and indicating cause for some caution.1,2,3

It is hard to tell whether those in the first camp are there because they have fully engaged with this issue and made a considered decision, or whether they have only minimally engaged. As authors we are probably in a third (undecided) camp. It adds weight to the issue to appreciate that with the proton beam arrangements and planning margins typically used, the area of highest and most uncertain biological effect (the proton distal edge) will most usually be in healthy tissue bordering the clinical target.

Looking to the future
This treatment may benefit a wider population than it will be possible to serve through the two NHS centres currently under development. Collaborative translational research will help to predict which patients will most from such treatment. A consortium led by University Hospital Birmingham, in collaboration with Birmingham Childrens Hospital, Royal Orthopaedic Hospital and University of Birmingham, was designated as the third NHS centre to cater for expansion. In addition the authors understand that a research facility will be developed in Oxford. ‘There’s no such thing as bad publicity’, or so the saying goes. Time will tell whether the recent publicity on proton radiotherapy is ultimately helpful to the subset of UK patients who need these treatments.

REFERENCES
see more common ground between art and science than contradiction. Artists and scientists share a common drive to observe, explore, question and innovate, and they have a similar mindset in approaching their work: the artist and the scientist must begin their day without preconceptions about the possible outcome of their research. They must be open to all ideas, including the supposedly ridiculous and impossible. They must empty their head of all previous knowledge and journey forth with the innocent vision of a child. If the outcome of research is preempted in any way, it will be subservient to expectation and therefore flawed. (Pascale Pollier, Karger Gazette, No. 73, page 12, October 2013)

In this quotation from an interview, Pascale Pollier was speaking about art and science, but she could equally well have been speaking about creative writing and science. Sadly, such a breadth of outlook is unusual.

The chasm that still separates the humanities and the sciences – the so-called ‘two cultures’ identified by C.P. Snow half a century ago – begins to open up at school. Some pupils opt for the humanities, not for any positive reason but because they feel temperamentally unsuited to the sciences. Unfortunately they then develop, and take into adult life, the conceit that they are engaged in a creative discipline and scientists are not. Most authors come from a humanities background so it’s not uncommon to encounter such an attitude. It seems to be rooted in a philosophical model of science that prevailed for some centuries: the notion that scientists make observations from which they deduce a theoretical explanation. The role of creativity in science is more realistically conveyed by the modern view, which draws from the work of the great twentieth-century philosopher Karl Popper.

Crossing the great divide

Stanley Salmons (Emeritus Professor, University of Liverpool) is a successful fiction writer. Here, he shares his tips to help aspiring writers venture beyond specialisms and into new landscapes of imagination and language, to cross the great divide from writing academic and scientific works to fiction that people will enjoy reading.
Philosophy of science
The scientific process doesn’t start on the laboratory bench at all: it starts in the head. A problem grinds away in the mind, provoking us to put forward a theory that may shed light on it. This involves both the urge to innovate and a willingness to reject received wisdom. We then use our powers of reasoning and knowledge of the cognitive field in an effort to falsify the theory. This usually results in that theory being rejected, and a new one has to be put forward. We repeat the process until, if we’re lucky, a leap of the imagination yields a hypothesis that appears to explain all the known phenomena. Even Eureka moments – such as Archimedes’ famous insight in the bath or Kekulé’s daydream of the benzene ring as a snake biting its own tail – come only after prolonged mental grappling with the problem.

The usefulness of a theory depends on its ability to make successful predictions. The next step – still in the mind – is therefore to draw predictions that can be tested experimentally.

This process, too, is widely misunderstood. Journalists – again mostly non-scientists – love to say scientists set out to prove a theory. Even if the result of an experiment is consistent with expectation it’s impossible to anticipate all the experiments that could conceivably be done, so we can in fact only disprove a theory. It may survive a minor conflict if suitably modified, but if it becomes overloaded with ad hoc assumptions it is ripe for replacement. What is chosen to replace it has to explain all the existing observations, whilst embodying the same or better predictive power in a more economical, and therefore more elegant, package. The choice is a purely aesthetic one. For example, it would take a good deal of hard evidence to shift the paradigm represented by $E = mc^2$, because of the simple beauty of its formulation. (My colleagues and I once tried to persuade a mynah bird to say $E = mc^2$. It declined to do so. Possibly it disagreed with the implications.)

Funding research
In the seventeenth, eighteenth and much of the nineteenth centuries, research was conducted almost exclusively by men of independent means. These days researchers are a less privileged community. Whereas those in the humanities need little more than a library ticket and a laptop, those who engage in experimental science need a level of support that is well beyond the ability, and certainly the inclination, of any institution to provide. The money must therefore come from grants.

Writing these grants requires a further, even more extreme, creative process, because it’s in the nature of original research that the outcome is unknown. We must nevertheless present a potential solution to a problem and devise an experiment or technique to overcome it, envisage all the possible outcomes of the experiment and how they may be dealt with, and anticipate the value of the expected results. Only when a grant application is successful can we finally approach the laboratory bench.

Progress in science therefore depends on imaginative insight to construct a theory with better explanatory power, coupled with a good grasp of where it fits in the context of existing knowledge, an aesthetic sense of what is elegant in both theory and experiment, and the ability to explore the implications. It also calls for the presentational skills needed to convince others of the value of the work. By every measure, scientific and engineering disciplines are closer to the humanities than the old and outdated models of philosophy would otherwise suggest.

Science and science-based fiction
Science-based fiction can certainly prosper in the hands of non-scientists – indeed, authors like Jules Verne, John Wyndham, Brian Aldiss and Harlan Ellison helped to lay its foundations. But the very people who research historical, geographical and social context with great diligence can be remarkably careless when it comes to scientific detail. Some simply fudge the issue by trotting out meaningless technicalities in the hope of blinding the reader. Even a much-respected storyteller can be guilty of this. In Daphne du Maurier’s The House on the Strand, Magnus, the biophysicist (sic), dismisses his concoction in the following terms: ‘It has to do with DNA, enzyme catalysts, molecular equilibria and the like – above your head, dear boy.’ The potion, which she refers to as a drug, includes ‘synthetic fungus’ and ground-up monkey’s brain, so she may as well have thrown in herpes B virus for good measure. As for Dan Brown’s science – well, it’s best to draw a veil over Dan Brown’s science.

Fantasy of this sort is written in the expectation that the reader is willing to suspend disbelief for the sake of following a good storyline, and it’s a step aficionados of the genre will be happy to take. All the same, as scientists we’d like to see the subject matter approached with more respect. So could we do better?

Where science, scientists or natural phenomena are at the core of a story, we arguably start at an advantage, because we have the right knowledge base and mind set. We are already at home in ‘what if?’ scenarios, and these are also the basis of much fiction writing. What if an exhumed body is not as old as it appears to be? What if you were a passenger on an aircraft you knew to have a fundamental mechanical weakness? What if humans were bred and cloned to yield a highly stratified society? What if space ships could travel faster than light?

Conceptually, then, it’s a small step from the world of science to the world of fiction. In practice, we’ll be confronted by a steep learning curve. Why is that?

Crossing the divide
Good scientific writing is tightly disciplined. I used to tell third-year undergraduates that scientists are engaged in marketing: persuading others to buy their ideas. Every sentence must carry the message forward clearly and unambiguously; sentences should link, A to B, B to C, C to D, and their length, as well as their internal organisation, should place the emphasis on the right words. On the larger scale, a paper, chapter, book or...
grant application should be written in strict sequence, drawing the reader through the text, developing the concepts and interpreting the data in a logical and orderly way.

Fiction, on the other hand, frequently starts at an exciting juncture, only to progress backwards and forwards, keeping the reader engaged whilst building the story and filling in the backstory. There is theme, plot and structure. There’s a need to establish time and place, develop the characters and their individual voices, incorporate conflict and resolution. There are choices to be made, techniques to master. Clearly a new skill set is needed. What’s the best way to acquire it?

You can design an experiment, describe the results and explore the implications

Paul Beatty, who wrote on the subject in the March issue of Scope, prepared himself by pursuing an MA in creative writing. This is a valid route, although it depends heavily on the quality of the chosen course. An Open University course in creative writing may be more convenient, and could well provide a more tailored experience. But not every retired scientist or engineer wants to take a course at all, and there are alternatives. Here are my own top tips.

1. Read a few books on the subject. Sol Stein is the doyen of mentors in this field, and either Solutions for Writers or Solutions for Novelists (Souvenir Press) will be high on the reading list of any formal course. I also recommend Self-editing for Fiction Writers by Renni Browne and Dave King (Harper), which covers the same ground in a less discursive fashion. There are some excellent online resources too, such as Emma Darwin’s This Itch of Writing (http://emmadarwin.typepad.com/thisitchofwriting/resources.html).

2. Write at least 30 short stories before attempting a novel. I forget where I read this, but it’s excellent advice. In the short story you can write in different genres, explore the differences between first, second and third person narrative, present and past tense, dialogue and free indirect style, and so on. Above all, you learn how to close the distance between the reader’s mind and mere words on a page.

3. Join a local writers’ group (by this I mean a committed writers’ group, not a mutual congratulation society). There is really nothing as valuable as getting critical feedback on your writing, especially when it comes from people with varied backgrounds. I’ve written over 40 short stories, of which 35 are published, and 12 novels, of which three are published and a fourth will be out in November, and I’m a member of the Society of Authors. But I lead two writers’ groups, one in Liverpool and the other in Chester, and I pay a lot of attention to the critiques I receive there. I’d go so far as to say that some recent novels by well-established authors would have benefited greatly from an airing in such a group. Just be aware that after this you will never read a book again in quite the same way!

As a very brief example of the process, let’s critique the following (concocted) passage. Tom and Jill are running from a man with a gun.

They rounded a corner and paused to rest for a moment. Tom was exhausted and he could see that Jill was, too. She was out of breath and her legs were so tired she didn’t think she could take another step. But fear was driving Tom on.

‘We must try,’ said Tom. ‘There isn’t far to go.’

‘All right,’ Jill sighed.

What’s wrong with this? The viewpoint is all over the place, so the reader doesn’t know whether they’re in Tom’s head, in Jill’s head, or with some narrator in the sky. We’re being told that they’re ‘exhausted’, but with a bit of physiology we can be made to feel it for ourselves. The phrase ‘he could see’ distances us from Jill; let’s see it for ourselves. Tom and Jill are the only characters in the scene, so there’s no need to use their names, and tags like ‘Jill said’ or the more archaic ‘said Tom’ can be avoided altogether, as long as it’s clear who’s speaking. Finally, by adding Jill’s actions we could lose the last line of dialogue.

Dealing with these issues gives us:

They rounded a corner. He pulled her against him and leaned against the wall, heart pounding. She was limp in his arms. Her voice, muffled against his chest, escaped between snatched breaths.

‘It’s… no good…I can’t go on.’

A rivulet of sweat trickled down his neck. He ran the tip of his tongue round his lips and swallowed.

‘We’ve got to. Come on. Not far now.’

She straightened up, wiping back a strand of hair that was sticking to her forehead. Then she sighed and took his hand.

Your novel may need multiple passes to bring it to life in this way. When you’ve done that you’ll want a readership. You can go along the traditional route, but you’ll have to be persistent. Agents and the larger publishers are no longer interested in nurturing talent; they’re interested in nurturing sales. When you’ve amassed a handsome collection of rejection slips you may consider self-publishing, but hundreds of thousands of titles are self-published each year, so you’ll have to be prepared to spend a good deal of time (or money) on promotion if you want your head to show above the parapet.

So why do it?

For a scientist or an engineer, fiction writing is incredibly liberating; you can design an experiment, describe the results and explore the implications – all without having to write a grant or even leaving your desk! You will broaden your existing knowledge as you venture beyond your own specialisms and into an exciting new landscape for the exercise of imagination and language. And how satisfying it is if your perseverance pays off with publication, and people start to enjoy your books!
Radiotherapy extended hours: manufacturers’ perspective

Alison J. Vinall (IPEM Radiotherapy Extended Hours Working Party) considers the implications from a manufacturer’s point of view

As part of the information gathering exercise for the IPEM working party on Extended Hours for Radiotherapy Services, a meeting was held with the main radiotherapy equipment manufacturers, which proved a fascinating insight into their perspective in providing a service to radiotherapy departments. Representatives from Varian Medical Systems, Elekta and Accuray were invited to meet with members of the IPEM working party (WP). In the event, only Varian and Accuray were available to attend on the day, but Elekta contributed via email and telephone. The manufacturers were offered the opportunity to meet with the working party members individually as well as together, in case they would compromise any commercial secrets, but they were all very open with each other and with the WP members. It was interesting to see the similarities but also some differences between them.

Discussion with the manufacturers

The manufacturers were asked to consider three working scenarios for extended hours, namely: (1) extended hours on weekdays outside Monday to Friday, 9am–5pm; (2) weekend working – Saturdays only in addition, and (3) full 7-day working. We also asked them to consider any ‘not possible’ scenarios which could be fed back into the report. In the event, there was nothing that was impossible but there will need to be some adjustment of expectations on the part of both Trusts and manufacturers, and an inevitable increase in resources, most notably staffing.

The discussion was very wide ranging. Varian and Elekta have a bigger customer base than Accuray and consequently have a larger pool of field service engineers (FSEs). Varian service approximately 250 linacs with 25 engineers; both they and Elekta have built their support model around working 9am–5pm Monday to Friday. Therefore, there will need to be an ethos change, as is happening elsewhere within the NHS, in order to provide cover outside of those hours. Varian currently work over 100 weekend days per year where individual sites have already negotiated a contract for weekend working, and any one engineer is working approximately six weekends per year. Varian estimated that they would need possibly 30 per cent more staff to change to a model in which weekend working is routine. Accuray currently have service contracts that run from 8am–9pm but they find there is often a problem with...
EXTENDED HOURS FEATURE

The manufacturers were all quite vocal about the problems they encounter

The manufacturers all regretted the demise of NRIG – National Radiotherapy Implementation Group – (as do we all!) and said that they felt Trust procurement departments were the ones carrying more sway, and their perception is that there is a danger that radiotherapy professionals are not being consulted about equipment. The problem with trying to sweat more out of existing equipment means that issues of increased complexity of equipment, training and recruitment of staff are not being taken into account. They all felt that the service efficiency machine model proposed by NRAG (National Radiotherapy Advisory Board) was to be recommended. I guess we would expect them to say that, but from their perspective there is less pressure on deciding how to deploy FSEs when multiple calls come in, and it removes the need to do servicing out of hours.

Varian are already reporting a sharp increase in the failure of x-ray tubes with the increase in IGRT, and also couches. Whilst the basic machine can continue treating for extended hours it is the more complex and often mechanical components that are failing more often. We can therefore expect more equipment failures with extended hours, although probably only in proportion to the increased workload. Although parts are manufactured with longevity in mind, there is also associated QA after replacement, which is also taking up more time.

Logistical problems

There are a number of logistical problems which are common to all manufacturers, such as warehouse staffing and delivery of spare parts. Staffing a warehouse out of hours is possible but the manufacturers are at the mercy of the courier companies and are a minimal industry as far as any bargaining power with them might go. Holding spare parts is expensive, and shipping even small parts for next day delivery can cost up to £1,000 per delivery. Obsolescence occurs during the lifetime of the machines and it is quicker to get whole components replaced rather than to repair on site. This all leads to increased shipping and delivery costs. Delivering spare parts at all times would mean that Trusts need to ensure they have 24/7 goods inwards departments with staff who are willing to assist with the offload of large items. There have been cases when a delivery driver has had to take an item away because it required two people to lift, and there has been no one at the hospital end to assist.

The manufacturers were all quite vocal about the problems they encounter with Trust IT departments, and the difficulties of remote access into Trusts for such things as problem solving, and internet access required on site. There are legislative issues with patient data leaving the EU to be investigated, so companies prefer to access in to avoid that issue. Better remote access would assist any extended hours programme so there is a need for Trust IT departments to work with manufacturers to resolve such issues, in order for extended hours working to succeed. The problems will be particularly acute for any software upgrades where the migration of the database is usually one of the first actions. The treatment service would not be able to run, so it is possible that if a department was working 7 days per week there would need to be a 2-3 day break for all patients receiving treatment at the time of a scheduled software upgrade.

The obsolescence of operating systems can be a problem, as well as their need for replacement. For example, some computers have to be replaced every 5 years, which results in challenges for manufacturers.

Conversely, the advantage of a 7 day per week service means that PPM and QA can be scheduled for any day of the week – not necessarily at weekends.

The longer-term view

Training of FSEs is an important issue for the manufacturers. They indicated that it takes about 10 months to train an engineer, hence the manufacturers would like some national agreement around moving to extended hours. They do not want to train a large cohort of engineers with the long lead-in time required and not have the guarantee that they would be needed for working extended hours. Manufacturers currently recruit from other engineering firms or use ex-RAF personnel. However, they think that this source will likely reduce in the future. They estimated that it would take them 2-3 years to put in place the infrastructure required to support extended hours working across the country.

All the manufacturers felt that the 10-year lifetime of a machine is sensible, whether a tomotherapy machine or a linac. Of course, manufacturers want to sell machines but they also pointed out that whilst you can upgrade to a point to keep a machine running, it is not economic to keep old machines going if you want better efficiency or better scope of treatment. Manufacturers have to go to subcontractors for components and having to change a supplier to keep an older machine working is problematic and expensive for them. They warned that 7-
day working would make the lifetime cost of a machine greater, which might cause problems for sales trying to win contracts (but I’m sure they would find a way!). There may also need to be a redefining of the concept of ‘downtime’. At the moment engineers can continue to work on a machine beyond 6pm and the machine is not considered to be ‘down’ for the purposes of downtime calculations. Again, these issues are not insurmountable but will require a slight culture shift to operate within a new working environment.

Subsequent to the meeting we asked the manufacturers to estimate the costs involved in supporting the three given scenarios for extended hours working. Interestingly, they did not feel that there would be much difference between the increased cost for extended hours during the week compared to providing a 6- or 7-day service. However, they did estimate an increase in costs of the order of 70 per cent over current service contracts.

In order for the manufacturers to better understand how many departments are currently working extended hours they would like calls to be logged on the helpdesk answerphone when they occur, rather than waiting until the next morning. This will help to give them an idea of the volume of calls during those times. They also bemoaned the fact that a number of Trusts do not currently include maintenance costs in their initial procurement contracts.

In conclusion, the manufacturers are aware that the provision of radiotherapy services across extended hours is likely to happen and indeed is already the case in some departments. They currently do not have the infrastructure to support extended hours on a national basis and their main concern is the need to significantly increase their staffing base. They wanted to point out that they too were living in a climate of trying to reduce overtime and overheads within their own companies! It is important that we, as a radiotherapy community, continue to engage and work with them, if possible with a national perspective, to ensure development of extended hours services in a safe and efficient manner.

The working party members wish to thank the manufacturers for a very free and open discussion, which gave valuable insight into their working, and the issues that affect their service provision to us.

REFERENCES

As part of the information gathering exercise for the IPEM working party on Extended Hours for Radiotherapy Services, a survey was produced and distributed via email to the UK Heads of Radiotherapy Physics in December 2013 to be completed as of 1st January 2014. The aim of the survey was to determine how much non-clinical time is required to support a safe, clinical RT service. Previous surveys focused largely on routine QA activities so it was necessary to extend the scope of the current survey to take into account changes in practice since 2008, including the significant increase in patient-specific QA, as well as tasks such as upgrades of equipment, commissioning and clinical trials, all of which require direct access to linacs and have previously not been reported. Departments were asked to return times for the activities along with the time of day when the activities were performed. Information was requested on the availability of decant bunkers and service efficiency machines, and on the availability of MPE support as well as funding for extended day working.

**Observations**

Replies were received from 32 of the 62 centres polled in the UK (approximately 50 per cent).

The responding centres reported a total of 164.5 clinical linacs, with the number of linacs per centre ranging from a maximum of 12.5 linacs, a minimum of two and a mean/centre of 5.1. This may be taken as a reasonably representative sample of small, medium and large departments when compared with the distribution of linacs/centre taken from the RT dataset (RTDS) for England which reports a maximum of 16, a minimum of two and a mean of 5.4.

**Operational hours**

For the purpose of discussion in this report, the ‘standard’ working week will be taken as 9am–5pm, Monday to Friday. However, responses indicated that many centres were already operating clinically on an extended day basis, with over 50 per cent of centres opening between 8am and 8.30am and a majority still operating at 6pm. Approximately 60 per cent of departments were running at least a 9-hour day with 40 per cent at least a 10-hour day.

Three departments reported routinely treating patients on a Saturday with a further four treating emergencies or category 1 patients on bank holidays.

**Linac servicing and quality assurance**

Centres surveyed were requested to provide information on when routine QA tasks and maintenance were performed. Whilst the data shows considerable variation between centres, on average centres reported undertaking a total of almost 2,250 hours per annum (including 1,000 hours of daily checks). Figure 1 indicates the breakdown of work, expressed as a percentage of the total time.

This equated to an average, excluding daily checks, of approximately 250 hours per annum per linac (of which 160 hours fall within the standard week), although there was significant variation in the amount of time used per linac and consequent time per centre. There appeared to be little correlation between the size of the department and the time used.

Further analysis indicated that:

- 70 per cent of monthly QA or inhouse servicing took place during the standard (working week).
- 10 per cent of centres used weekends for some elements of QA and inhouse servicing.
- 60 per cent of the (separately categorised) annual inhouse servicing was performed during the standard working week with 40 per cent being performed at weekends.
- 75 per cent of annual QA was performed during the standard working week.

With regards to manufacturer servicing, the following observations can be made:

- In centres where manufacturer monthly servicing was reported, this was done only on weekdays, with 80 per cent of this being done in standard hours.
- 85 per cent of manufacturers’ annual servicing was performed in standard hours on weekdays.
- Additional planned preventative maintenance including manufacturer preventative maintenance inspections, where stated separately, was largely performed Monday to Friday (75 per cent) with 25 per cent at the weekends.

It was not possible to break the data down any further due to the limited nature of the questions and the responses obtained.

**Patient-specific quality assurance and treatment plan validation**

The average delivery rate for IMRT over the period of the survey (October–December 2013) was 27 per cent of all radical patients.
**FIGURE 1.** The breakdown of linac QA and servicing activities as a percentage of the overall time – average of 2,250 hours per annum per centre.

- Daily checks, 45%
- Monthly QC, 20%
- Weekly checks, 11%
- Inhouse upgrades, 4%
- Audits, 2%
- Annual intercomparisons, 5%
- Training, 6%
- Maintenance, e.g. database backups, 8%
- Clinical trial work/R&D, 13%
- Manufacturer upgrades and post-upgrade acceptance and testing, 18%
- Service/technique developments, 14%
- Commissioning new equipment, 30%
- Miscellaneous other QA, 3%
- Annual servicing (manufacturer), 2%
- Annual servicing (inhouse), 2%
- Monthly servicing (manufacturer), 1%
- Monthly servicing (inhouse), 9%
- Annual QA, 2%
- PPM other (includes quarterly PMI), 5%
- Miscellaneous other QA, 3%

**FIGURE 2.** The breakdown of additional linac-based activities as a percentage of the overall time – average of 1,500 hours per annum per centre.

- Inhouse upgrades, 4%
- Audits, 2%
- Annual intercomparisons, 5%
- Training, 6%
- Maintenance, e.g. database backups, 8%
- Clinical trial work/R&D, 13%
- Manufacturer upgrades and post-upgrade acceptance and testing, 18%
- Service/technique developments, 14%
- Commissioning new equipment, 30%
Approximately 65 per cent of IMRT patients and 50 per cent of SRS/SABR patients had routine measurements, averaging 20–25 minutes per patient, followed by analysis of the results. The proportion of plans verified varied between departments, some measuring all plans whilst others QA a limited number for a new treatment site, then use a combination of sampling and software-based methods for verification.

IMRT QA measurements dominated the patient-specific QA time required for the techniques above, typically > 3–4 hours/week for the larger (>5 linac) departments with 70 per cent of centres undertaking patient-specific QA outside the standard working day.

Additional linac-based activities
Other essential activities, such as commissioning of new dosimetric equipment, system upgrades and testing, service developmental work, clinical trials work, R&D, training, dosimetric inter-comparisons and computer system backups, were also audited.

The survey found, on average, that approximately 1,500 hours are required per centre (or approximately 300 hours per linac) per annum for such activities. The relative distribution of activities is illustrated in figure 2. Over 50 per cent of these tasks are performed outside the standard day, with 28 per cent being performed before 9am or after 5pm, and 24 per cent being performed on weekends. It is clear that time needs to be protected in any extended hours treatment regime to allow these activities to continue.

Availability of service efficiency machines (SEM) and/or decant bunkers
The NRAG report3 recommended that centres should be in the position of having a SEM to minimise the impact of QA on capacity and a spare/decant bunker to maintain capacity through a linac replacement programme.

The survey indicated that there was a significant under-provision of both resources:
- Six of the 32 responding centres (19 per cent) had a SEM*.
- Sixteen of the 32 (50 per cent) had a spare decant bunker.

Departments with a SEM tended to run over a significantly (P < 0.05) longer average clinical day (10.2 hours) compared to the average for those without (9.2 hours), with the standard deviation in the mean in each case of approximately 1.0 hour.

*The survey does not contain sufficient detail about SEMs to determine whether they were ‘spare’ state-of-the-art machines or older machines called upon when necessary to deliver more basic treatments.

Availability of medical physics expert advice
There appeared little consensus from the survey response surrounding how formalised the role of the medical physics expert was in respect of extended day working.

Seven out of 32 (22 per cent) centres indicated they had either onsite or formal telephone access to an MPE during operational hours, with 25 out of 32 (78 per cent) centres reporting having either an informal telephone contact or no guaranteed access to MPE advice.

It is important for each department to determine safe staffing levels and the availability of appropriate levels of experience of staff supporting extended day working against the level of service being provided.

Summary
From the data gathered in this survey it was clear that in a majority of centres radiotherapy physics services are already engaged in considerable amounts of work outside of the standard 9am to 5pm day. The breakdown of physics activities in terms of hours spent in the average centre was as follows:
- 1,250 hours linac servicing and QA, excluding daily QA (approximately 250 hours per linac);
- 200 hours patient-specific QA;
- 1,500 hours additional linac-based activities (approximately 300 hours per linac).

There was significant variation in the data between departments nationally and as such it was not easy to prove significant correlation of the figures as a function of departmental size. However, these figures are consistent with those published following the last survey in 2008.12

Access to linacs is required for a range of activities essential to maintain the radiotherapy service, such as commissioning of new dosimetric equipment, system upgrades and testing, service developmental work, clinical trials work, R&D, training, dosimetric inter-comparisons and computer system backups.

Validation of complex plans by measurement on a linac will continue to be required during the introduction of new treatment techniques and for routine complex treatments. Extending the clinical hours of work impacts significantly on the access arrangements for these measurements unless they are scheduled during the clinical day.

The total of approximately 3,000 hours per annum is equivalent to the order of a full year’s linac-based activity over and above the patient treatment activity in the centre. It is vital that this time remains available if further extended hours regimes are required. Full availability of service efficiency machines and decant bunkers across the country will clearly need to be ensured to allow the provision of the necessary radiotherapy physics service under these circumstances.

REFERENCES


Radiotherapy extended hours: challenges for physics services

Gill P. Lawrence (IPEM Radiotherapy Extended Hours Working Party) outlines the challenges that the physics service will face

In September 2013 a working party comprising a number of Heads of Radiotherapy Physics and representatives from the Radiotherapy Special Interest Group (RTSIG) was established to explore the impact of increasing the hours of access to radiotherapy for patients. The working party and its subsequent position statement arose due to a number of factors. In 2011 a report from the National Audit Office\(^1\) identified that linear accelerators (linacs) were high value and recommended a review of the clinical hours of use for such items of equipment. However, the report acknowledged that there was uncertainty about whether patients would be willing to attend outside the then core clinical hours of service, namely 9am to 5pm. This contributed to the National Radiotherapy Implementation Group (NRIG) initiative over the summer of 2012 when an extensive patient survey was undertaken. The results from this survey indicated that a significant number of patients would be willing to attend for radiotherapy outside the core hours, at weekends and on bank holidays.

As a consequence, NRIG organised a multidisciplinary meeting in early 2013 to understand the current extent of extended hours working and to explore the possibility of developing some guidance for centres considering long-term routine extended hours access. In September 2013 Sir Bruce Keogh outlined plans to drive 7-day services across the NHS, which will...
EXTENDED HOURS FEATURE

Support is a key element to hold the process together

Impact on radiotherapy services in the longer term, and in early 2014 a Cancer Research UK document made reference to the need for extended hours working whilst noting that the benefits would have to be set against affordability in terms of staffing costs and the need for additional workforce capacity.

The NHS is increasingly patient focussed, with services being configured to ensure the patient receives the same standard of treatment whenever they attend. As much of the radiotherapy physics activity is undertaken in the absence of a physical patient, one of the current challenges for the radiotherapy scientific and technical community is to raise the profile of what we do in a patient-orientated culture. Similarly, the essential planned maintenance, quality assurance or service development has often been fitted around the clinical service, traditionally with scientists and technologists working in the evenings after the clinical service has finished or during weekends. This has minimised the impact of their work on the clinical service but has in many instances resulted in a quite invisible presence in the radiotherapy centre. Other staff and the majority of patients are unaware of the extent of the work that is undertaken and the resources required to ensure a safe and modern radiotherapy service.

The working party aimed to quantify the time resource necessary to support the clinical service, infrastructure and development of modern radiotherapy techniques to enable these factors to be included in the national report on increasing access to radiotherapy.

It is notable that a significant proportion of the work undertaken by the scientific and technical staff in a radiotherapy centre is not directly patient orientated but essential for the safe delivery of radiotherapy. A safe, resilient infrastructure requires commissioning when initially installed, of both imaging and treatment equipment and specialist software. Routine ongoing maintenance, planned and corrective, and regular quality assurance is also essential. Upgrades are regular features of a radiotherapy environment, which require time to undertake the upgrade and then validate the integrity of the radiotherapy processes afterwards. The time required for these activities is reported in an accompanying article. As increasing access to radiotherapy by extending clinical hours is planned, the resources to ensure an ongoing safe environment have to be factored in to any operational model that is developed.

Manufacturers’ planned preventative maintenance sessions, which may extend over two or three days, are required every four or six months. During the clinical week these necessitate the clinical activity to be cancelled on the linac, so treatments have to be reallocated to another linac or cancelled for those days. An awareness of the impact of this activity on the clinical scheduling of a radiotherapy centre led the working party to engage with the major equipment manufacturers to explore the impact of extending the clinical hours and this is reported in the article on page 17.

Complex treatment plans

As stated previously, radiotherapy physics staff are closely involved in the patient pathway from referral to the end of treatment without necessarily coming into direct contact with the patient. A complex treatment plan requires time for an ongoing multidisciplinary dialogue with clinicians, radiographers, dosimetrists, scientists and clinical technologists to ensure an appropriate technical treatment strategy is developed. Scientists, clinical technologists and dosimetrists are all integral in the preparation and customisation of treatment plans for each patient and validation of the integrity of each plan prior to the start of treatment. Validation of the integrity of the treatment plan is often established by the use of a calculation using software independent of the original treatment planning system. The important time metric during the treatment planning phase is cancer waiting time targets which have to be met. Sufficient numbers of radiotherapy physics staff have to be available to deliver a timely service and avoid unnecessary delays.

A significant increase in the use of complex treatments such as intensity-modulated radiotherapy (IMRT) and stereotactic ablative radiotherapy (SABR) has taken place over the past few years, partly funded by the Radiotherapy Innovation Fund. This has led to increasing numbers of individual patient plans being verified by direct measurement of the intended treatment plan on the linacs instead of being verified by calculation. Whilst more sophisticated monitor unit calculation software is becoming available, it is anticipated that all new treatment procedures will need to be validated by direct measurement for a significant time after initial introduction. This requires access to the linac for direct measurement of individual patient treatments and this resource, both personnel and time, has to be factored in when extending the clinical access hours and also any increase in clinical activity.

Presence of a qualified clinical scientist or medical physics expert

Many courses of treatment involve multiple treatment fractions delivered over several weeks, which are often delivered without any technical problems being encountered. However, in a number of cases scientific advice is required at a fraction due to a change in patient condition or a technical issue with the linac. During current conventional hours of clinical service a suitably qualified clinical scientist or medical physics expert (MPE) could be expected to be available to resolve technical problems experienced during a single treatment
episode and prior to the next fraction. Extending the clinical hours of service requires a decision on whether an MPE or experienced radiotherapy physicist is required to be present in the radiotherapy centre during all the hours of clinical service.

The presence or otherwise of an MPE or experienced radiotherapy physicist is a contentious issue and may depend on the patients selected for treatment during certain times of the clinical service. For example, the probability of there being an issue with a treatment fraction is dependent on the condition of the patient and the site of treatment. Selecting a cohort of patients where technical problems are considered unlikely may reduce the necessity for the presence of radiotherapy physics support in the radiotherapy centre compared to when a more challenging cohort of patients is being treated. It is important to acknowledge that there is always the possibility for an unforeseen problem to arise which would require scientific or technical advice. Hence access to an MPE would be essential prior to the next scheduled treatment fraction, which could be anticipated to be within 24 hours. An on-call rota of telephone support may be considered an adequate alternative.

Radiotherapy technology continues to develop and new clinical procedures are continually being implemented. All new clinical procedures have to be commissioned and validated; this invariably requires access to linacs, imaging devices and specialist software to complete. This work has traditionally been carried out in the evenings and at weekends, but will have to be scheduled as clinical hours are extended. An estimate of the current access required is outlined elsewhere.

**Challenges to be faced**

The challenges of extending access to radiotherapy will require a significant number of factors to be addressed. However, there are already a number of centres who have increased access to the clinical service either by extending the weekday service into the evening or at the weekend, with scientific and technical staff working outside the traditional hours of working to respond to local demands.

Recent reported experience suggests that the challenges of increasing access were greater in smaller radiotherapy centres (two linacs) where fewer staff were available to cover extended hours and maintain the clinical service at those times. The impact of equipment upgrades or downtime was also more significant as this affected a larger percentage of the clinical activity. In general, larger radiotherapy centres have more resilience in their infrastructure with more staff available to cover limited extended hours and more equipment available to provide alternative treatment facilities in a downtime or upgrade situation.

Resilience in the equipment capacity during extended clinical hours can be provided by ‘matched’ linacs, where the treatment delivery functionality is the same on both linacs. The clinical activity during extended hours is scheduled on one linac; if this fails then the activity can be transferred to the second matched linac without compromising the quality of treatment and avoiding the necessity of technical engineering staff to be available.

Some centres have negotiated non-standard working hours to facilitate increased clinical access with staff working four extended days out of seven. Others have extended clinical hours during a 5-day week and to ensure continuity of clinical activity carry out the majority of planned maintenance and quality assurance at the weekends, again with negotiated non-standard working hours.

The majority of centres currently operating extended hours do not deliver an extensive clinical service during those times, but carefully select the patient cohort to be treated, thus limiting the number and range of expertise of scientific and technical staff required to be available in the centre for immediate support or problem solving.

However, any permanent, significant increase in access to radiotherapy will require an increase in staffing resources at all levels due to the extended hours and increase in activity. This will impact on future training requirements as across the UK additional staffing resources at all levels will require training.

Increased clinical access at the weekend offers the opportunity to establish whether the accepted fractionation of five daily treatments per week is the optimal fractionation when compared to seven daily fractions per week.

**Conclusion**

In summary, the position statement issued by IPEM has documented the range of scientific and technical services required to maintain the radiotherapy infrastructure, provide scientific and technical support to the clinical service and deliver ongoing technical developments. Extending the clinical hours within a radiotherapy centre requires adequate time to be scheduled for the range of activities required to ensure a safe and modern infrastructure. Increasing clinical radiotherapy activity will require additional scientific and technical staff to deliver the service.

Whilst this work was undertaken within radiotherapy physics, the three basic requirements of infrastructure maintenance support, support for the clinical service and ongoing clinical service development are all pertinent to other areas of medical physics and engineering.

**REFERENCES**

Exploring the new frontier in medicine: nanotechnology

Tamas Szakmany (Consultant Intensivist, Cwm Taf UHB, Senior Lecturer in Intensive Care, Cardiff University) on developments in nanotechnology

This article is based on the presentation given by Dr Tamas Szakmany at the Philips National Biomedical and Clinical Engineering Conference in Birmingham, UK, on 17th October 2013.

‘What if there were such a thing as micromachines for use in medicine? You could put a mechanical surgeon inside a blood vessel. It would go into the heart and “look around”, find out which valve is the faulty one and take a little knife and slice it out.’

This was the theoretical concept proposed by physicist Richard Feynman in 1959. In a radical lecture entitled ‘There’s plenty of room at the bottom’, given at an American Physical Society meeting at The California Institute of Technology, Feynman extrapolated the vision of his friend, mathematician Albert R. Hibbs, suggesting that there were some interesting possibilities for very small machines. He claimed that it should be possible to make machines at a nanoscale that ‘arrange atoms the way we want’, and perform chemical synthesis by mechanical manipulation. This lecture was the birth of the idea and study of nanotechnology. What Feynman and Hibbs considered science fiction at the time is today becoming a reality.

What is nanotechnology?
The term ‘nanoscience’ is literally the science of tiny things. It’s not biology, physics or chemistry. It’s all sciences that work with the very small. At a nanoscale, different particles, atoms and metals behave completely differently. Research in nanoscience is an interdisciplinary knowledge-generating activity that strives to understand these laws and how they govern the behaviour of nanoscale objects. Nanotechnology is the creation of functional materials, devices and systems, through the understanding and control of matter at dimensions in the nanometer scale length.

What is nanoscale?
Considering a football is a good way to imagine nanoscale. The football is 10 million times smaller than Earth. But a fullerene – a spherical carbon molecule – is 1 billion times smaller than a football. This is nanoscale (figure 1). It is much smaller than the cells and bacteria that we deal with. For example, a cubic micron of water contains about 90 billion atoms. A micron is one-thousandth of a millimetre, and a thousand times larger than a nanometre.

With nanotechnology, the limits of our imagination are being redefined. It allows scientists and engineers to build
entirely new materials or machines that we may previously have thought impossible. It is the stuff of Star Trek; we can now really think outside the box.

**Market projections**
The US market for nanomaterials (which totalled only $125 million in 2000) is expected to reach $35 billion by 2020 (figure 2). Early growth came from numerous niche applications that span the entire US manufacturing sector. These include wafer polishing abrasives and high-density data storage media for the electronics industry; improved diagnostic aids for the medical community; transparent sunscreens, stain-resistant pants and wear-resistant flooring for consumers; cost-cutting equipment coatings for the defence industry; fuel-saving components for the auto industry; and better paper and ink for the printing industry. In the long run, however, the best opportunities are expected in healthcare and electronics, which together are expected to comprise nearly two-thirds of the market by 2020.

**Nanotechnology in medicine**
Since artificial nanostructures are of the same size as biological entities, they can readily interact with biomolecules on both the cell surface and within the cell itself. Nanotechnology in medicine really took off in the 1990s, aiming to improve treatment and prevention of health problems. In 1995, Doxil became one of the first nanomedicines to be approved by the US Food and Drug Administration (FDA). Doxil contains coated liposomes that reduce the damage to the heart by the conventional drug Doxorubicin. As a nanoformulation, the drug reduced the severe side effects that previously limited its use, and Doxil was approved for the treatment of AIDS-related Kaposi’s sarcoma and later for ovarian cancer and bone marrow cancer.

Today, nanomedicines are used in analytical and imaging tools, theranostics (a diagnostic process to determine the most effective treatment), targeted drug and delivery systems, tissue engineering and regenerative medicine. Discoveries are translating breakthroughs in the understanding of disease into preventive medicine and creating opportunities for more affordable healthcare.

**Targeted cancer treatments**
Cancer treatment represents the largest therapeutic area for approved nanomedicines, as well as for patents and research publications. These mainly fall into two categories: to develop cures for traditionally incurable diseases through the utilisation of nanotechnology; or to provide a more effective cure with fewer side effects by means of targeted drug delivery systems.

Tumour penetration is a key issue for successful chemotherapy. Scientists have designed polymerised nanoparticles to bind to specific markers within cancer cells. The nanoparticles circulate through the blood vessels until they reach the target cells and drugs are released. Because of their small size, nanoparticles can pass through spaces between different types of cells. As tumour cells typically have larger interstitial spaces than healthy cells, the particles collect in the centre allowing the drug to kill the tumour from the inside out (figure 3). This process allows for considerably higher, more effective doses and the preservation of healthy cells.

Gold is also being used to deliver highly-targeted anti-cancer treatments. It behaves differently at a nanoscale and its properties are altered. Mass gold reflects light but, in contrast, particles of nanogold are small enough to scatter visible light.

Current US clinical trials in the treatment of patients with head and neck cancer involve the intravenous injection of AuroShell particles, comprising a silica core coated with an ultra-thin gold shell. These are not drugs – they are specifically designed molecules that bind to cancer cells. Once these particles have accumulated inside the tumour, the area is illuminated with a near-infrared laser at wavelengths that allow penetration through healthy tissues without harming them. The metal in the AuroShell particles converts the absorbed light into heat that destroys a tumour from within (figure 4). Theoretically, this technology could be useful for the eradication of all solid tumours, including breast, prostate and lung cancers. However, the toxicity of gold has not yet been fully investigated.

**Nanotechnology in the intensive care unit**
Although most new trials are focussing on cancer, nanomedicine can be very effective in combating sepsis, which is a bigger killer than both breast and colon cancers combined.

The treatment of multi-drug-resistant bacterial infections is a great challenge for medicine. The Institute of Bioengineering and Nanotechnology (IBN) has developed peptide nanoparticles that can treat infections that do not respond to conventional antibiotics. Biological ‘nanofactories’ are engineered to trigger communication between different bacterial populations. These nanofactories can trick the bacteria into trying to form an infection before there are enough bacterial cells to do harm. This, in turn, would prompt a natural immune system response capable of stopping the bacteria without the use of drugs.

On a nanoscale, silver can be used to combat infection in a variety of ways. Silver ions can easily reach into the nucleus of a germ, where its vital gene pool is located. Once silver ions combine with these genes, the genes become paralysed and the germ cannot replicate itself.

**FIGURE 1.** An illustration of nanoscale
Most recently, it was discovered that silver, when tied to oxygen, can actually electrocute the germ.

UPOSH (uniform picosomal oligodynamic silver hydrosol) uses the purest silver molecules of the tiniest size to penetrate super-bugs, killing them from the inside out. This use of nanotechnology can also be applied to antiseptic-coated catheters and dressings to prevent the spread of infection.

We can also use nanoantibiotics as a superior alternative to existing treatments for brain infections. The brain membrane is impenetrable to most conventional antibiotics because the molecular structure of most drugs is too big to cross the blood–brain barrier. But IBN’s peptide nanoparticles can traverse this barrier, allowing the nanoantibiotic to reach the infected areas of the brain that require treatment.

**Consequences for the future**

Nanoscients can now engineer new DNA sequences and get them into cells to try to change their functions. This has previously been achieved using ‘viral vectors’ which can trigger immune responses, and even death. But new synthetic nanostructured molecules such as dendrimers can potentially deliver DNA into cells during gene therapy, without this risk. The dendrimer’s branched structure also makes it highly effective.

But being able to alter the DNA sequence of a target cell is not without hazards and concerns. Experts report that smaller particles are more bioactive and toxic. Their ability to interact with other living systems increases because they can easily cross the skin, lung and, in some cases, the blood–brain barriers. Once inside the body, there may be further unexpected biochemical reactions like the creation of free radicals that damage cells.

The National Institute for Occupational Safety and Health (NIOSH) in the US is already engaged in raising awareness of the issues involved with nanotechnology. It will make recommendations on occupational safety and health best practices in the use of nanomaterials. We do not know how these therapies and products will affect the human race – and indeed the whole environment – but it is certain that nanotechnology applications will soar in the next five years.

Read more... Dr Szakmany’s full slide presentation is available at: www.philips-events.co.uk/Tamas-Szakmany

**RESOURCES**

**Must-read books**

- *As the Future Catches You* – Juan Enriquez
- *The Investor’s Guide to Nanotechnology and Micromachines* – Glenn Fishbine
- *Hacking Matter* – Wil McCarthy

**Periodicals**

- *Forbes/Wolfe Nanotech Report*
- *MIT Technology Review*
- *Science*
- *Nature*
An invitation to the House of Commons

Jenny Marsden (Principal Physicist, Hull and East Yorkshire Hospitals NHS Trust) gave her views on women in science and how the government can help.

As the IPEM newsletter now arrives by email, I usually glance at the headlines and aim to set aside some time later to look through the articles. However, this time, in August, I was drawn to the section on ‘How IPEM is working for you’ and saw that ‘we’ were responding to a consultation on women in science. Interesting, I thought. What might IPEM have to say on this issue? I don’t recall them asking me! I must read this now!

As I reviewed the response from Dr Peter Jarritt and the associated survey collated by Dr Jamie Harle, I was struck with the realisation that despite huge advances in equal opportunities for women, the situation is still unbalanced and, disappointingly, women are still underrepresented, especially at more senior levels in physics and engineering in medicine. The survey response itself was disappointing; 11 respondents out of 21 female academics highlighted from the IPEM’s Academic Advisory Group… is that all? My mother would be saddened to see those numbers, having instilled in her girls an ‘all is possible’ outlook on life, and how could I explain to my daughter in the future that a fulfilling career in science may well be cut short for her if she decided to have a family, or fell in love with someone with an equally demanding career or, worse, had to look after me!

Invitation to give evidence

So I decided to write a personal submission to the Science and Technology Select Committee Inquiry into Women in STEM Careers. Picture my surprise when I was selected from the 90 other respondents to give evidence in person to the committee in the House of Commons!

On 16th October 2013 I attended the oral evidence session at Portcullis House and sat in front of 11 MPs (interestingly only one was a woman) who asked the panel of three various questions related to our submissions. How could we stop the tide of women leaving science? What could the government do to improve things? Why was there such an appalling ratio of women to men at the most senior posts in the scientific world?

I don’t imagine that I gave any groundbreaking ideas or revolutionary theories. The experience was exhilarating but also disheartening. The fact is, girls are turned off science as early as primary school. Worse is when excellent scientists, often at post-doctoral level, are lost because there is little flexibility in working arrangements, childcare provision, grant access and too much geographical uncertainty. I did, however, research what I wanted to say and felt that I had the opportunity to say it. (Thank you to Rosemary Cook who provided me with the IPEM male/female membership statistics across committees and grades which is quite well balanced… apart from at the level of ‘Fellow’.)

Flexibility in the workplace

I spoke about the need for true flexible working and the provision of paid parental leave for both male and female parents. I feel that if we alter the cultural norm that women attend to the children and the home and, if we can support men to take a more equal role (such as in Sweden), then stereotypes will gradually change. I spoke about the need for women to get to senior grades so that there is fair and equal representation at the level of policy makers. I discussed the problems with presenteeism and the self-perpetuating issue with the gender pay gap; the person earning the least money will be more likely to give up their job to take on the necessary caring role.

Finally, I tried to mention the professional and personal benefits of a scientific career, that studying science should enable an individual to achieve many goals in life including access to various careers. I stressed the importance of believable role models for children and about informing and educating the public about the wonderful world of science, something which is at the heart of the IPEM’s charitable aims and that I know other IPEM members, both female and male, feel very strongly about.

The final report has not been published yet but for those interested, all the responses supplied to the Select Committee can be found online by searching for ‘Women in STEM’ or going to www.parliament.uk. You can also view videos and read transcripts of the proceedings.
With prostate cancer being the most common cancer in men in the UK, there is an impetus to improve the quality of treatment to produce the best clinical outcome. Intensity-modulated radiotherapy (IMRT) has become a method widely used to treat patients with prostate cancer. The ability to deliver a homogenous and highly conformal dose to this target organ means that it is possible to reduce toxicity and therefore potentially improve the patient’s quality of life post treatment.

The process of IMRT/VMAT plan generation is labour intensive. The resultant treatment plan quality is dependent on the knowledge and skill of the dosimetrist controlling the treatment planning software.

In this study, a team from the Erasmus Medical Centre, Rotterdam, The Netherlands, have developed Erasmus-iCycle, an algorithm that is able to fully automate the optimisation of the treatment plan. The system uses multicriterial beam profile optimisation and beam angle selection.

Thirty prostate cancer patients were selected for treatment at Erasmus Medical Centre between January 2012 and January 2013. All patients had four gold fiducial markers implanted in the prostate to aid the monitoring of inter- and intra-fractional movement.

The patients were all CT scanned. The prostate and other related structures were delineated according to Radiation Therapy Oncology Group (RTOG) guidelines.

The automated VMAT plans were generated in a two-step approach. Erasmus-iCycle was used to automatically generate 23 equally spaced 10 MV IMRT beams. At the time of this study, Erasmus-iCycle was unable to produce clinical VMAT plans itself and so a two-step automated approach was adopted. Plans were produced using the MCO engine within the software. Based on the constraints and objective values achieved in these plans, a bespoke patient template is produced. This template contains all of the information needed to drive treatment planning software.

### TABLE 1.

Comparison of plan parameter for the organs at risk for each of the study groups, showing mean differences, standard deviations, difference ranges and P values.

<table>
<thead>
<tr>
<th>VMAT\textsubscript{man} - VMAT\textsubscript{auto}</th>
<th>GROUP 1</th>
<th>GROUP 2</th>
<th>GROUP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± 1SD</td>
<td>Range</td>
<td>p-value</td>
</tr>
<tr>
<td>Rectum V75Gy (%)</td>
<td>0.3 ± 0.7</td>
<td>[-0.8, 0.7]</td>
<td>NS</td>
</tr>
<tr>
<td>Rectum V60Gy (%)</td>
<td>1.2 ± 1.4</td>
<td>[-1.8, 3.2]</td>
<td>0.028</td>
</tr>
<tr>
<td>Rectum Dmean (Gy)</td>
<td>2.1 ± 1.7</td>
<td>[-1.6, 4.0]</td>
<td>0.013</td>
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<tr>
<td>Anus Dmean (Gy)</td>
<td>0.8 ± 2.5</td>
<td>[-2.4, 6.3]</td>
<td>NS</td>
</tr>
<tr>
<td>Bladder V65Gy (%)</td>
<td>0.4 ± 1.1</td>
<td>[-1.2, 2.0]</td>
<td>NS</td>
</tr>
<tr>
<td>Bladder Dmean (Gy)</td>
<td>0.4 ± 1.5</td>
<td>[-1.3, 2.4]</td>
<td>NS</td>
</tr>
<tr>
<td>Right Hip Dmax (Gy)</td>
<td>-0.3 ± 1.8</td>
<td>[-4.8, 2.2]</td>
<td>NS</td>
</tr>
<tr>
<td>Left Hip Dmax (Gy)</td>
<td>0.2 ± 1.7</td>
<td>[-1.9, 3.0]</td>
<td>NS</td>
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</tbody>
</table>

\* TABLE 1. Comparison of plan parameter for the organs at risk for each of the study groups, showing mean differences, standard deviations, difference ranges and P values. ABBREVIATIONS: VMAT\textsubscript{man} = VMAT plans generated manually by 1 expert dosimetrist in the absence of time pressure; VMAT\textsubscript{auto} = automatically generated VMAT plan. Positive values point at lower parameter values for VMAT\textsubscript{auto} when compared to VMAT\textsubscript{man}. NS = statistically not significant (i.e., P > .05). Table kindly supplied by Peter Voet, Department of Radiation Oncology, Erasmus MC Daniel den Hoed Cancer Center, Rotterdam, The Netherlands. © 2014 Elsevier. Fully automated volumetric modulated arc therapy plan generation for prostate cancer patients. Int J Radiat Oncol 2014; 88(5): 1175–9. http://dx.doi.org/10.1016/j.ijrobp.2013.12.046
second fully clinical treatment planning system (Monaco, Version 3.3, Elekta AB, Stockholm, Sweden) automatically opens the patient data, imports the template and calculates a deliverable single arc VMAT treatment plan based on the values within the template. As a benchmark for the automated VMAT plans, an expert dosimetrist manually generated VMAT plans without prior knowledge of the automated plans.

The automated VMAT plans showed very similar target volume coverage, with only small differences in dose to the OARs. All plans met the desired planning criteria. The plans generated using the automated system were dosimetrically equal to that produced by the standard method, whilst taking about half the time to produce and with no manual interaction with the system needed. Based on the results of this study, this system has been implemented clinically, thus meaning all prostate cases at Erasmus are now planned using this automated approach.

**Figure 1.** Comparison of rectum, bladder and anus plan parameters between VMATauto and VMATman for the three study groups. Each marker represents a parameter comparison for one of the study patients. For data points to the right of the unity line, VMATauto yielded better sparing. VMAT = volumetric modulated arc therapy; VMATauto = automatically generated VMAT plan; VMATman = VMAT plan generated manually by one expert dosimetrist in the absence of time pressure. Figure kindly supplied by Peter Voet, Department of Radiation Oncology, Erasmus MC Daniel den Hoed Cancer Center, Rotterdam, The Netherlands. © 2014 Elsevier. Fully automated volumetric modulated arc therapy plan generation for prostate cancer patients. Int J Radiat Oncol 2014; 88(5): 1175–9. http://dx.doi.org/10.1016/j.ijrobp.2013.12.046

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**CLINICAL TECHNOLOGIST EDITOR COMMENTS:**

I know that readers of this article, fellow dosimetrists, will probably be alarmed by me highlighting this paper. However, this seems to be one of the latest directions of research in our field. The ability to automatically plan a treatment could allow for true adaptive planning, creating a corrected plan accounting daily for any anatomical changes. This, in theory, could be accomplished with minimal impact on the dosimetrist’s workload.

The Rotterdam group are not the only people moving in this direction, but the fact that this system is good enough to be used clinically cannot be ignored. These types of automation systems are being developed and included in treatment planning software as we speak. I personally see it as a positive with regards to the ability to reduce clinical workload and speed up the process of planning and delivering high-quality radiation therapy. I believe it is our role as clinical technologists to be aware of new technologies such as this, and to be able to embrace and adapt to the inherent changes that such technology will bring to our role.

What are your thoughts on this topic? Do you see this as the beginning of the end for dosimetrists or do you see it as progress? Email me at Trevor.williams@uhb.nhs.uk

Peter Voet, the author of this work, commented in recent private communication (2014) that ‘...in my opinion the automation of treatment planning will allow a radiotherapy department to change focus in the direction on online adaptive techniques. Highly qualified personnel will become available due to the plan automation.’
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This year I decided I wanted to go to the two full-day education sessions that are run immediately before the conference proper, but how to fund it? I’d already been given the conference fees by my department; where was the remaining balance to come from? Earlier in the year I had attended my first trustees meeting in my capacity as VP for external relations, and during the agenda the President mentioned that there hadn’t been much uptake on the travel bursary scheme. In the past I had always thought that it didn’t really apply to me. Why? I think I had previously thought that there was only one travel bursary, that ‘American one’, but in fact there is just a pot of money that can be applied for, however much you need, and each case is reviewed on its merit. This seemed the perfect case.

Why did I want to do the education sessions? See figure 1. In particular, I was keen to expand my knowledge of whole-body MRI and MRI application in oncology. The first day was spent at ‘MR physics for physicists’. I find it’s always good to top up

**FIGURE 1.** Snapshot of the two-day educational programme found at [http://www.ismrm.org/14/14program.htm](http://www.ismrm.org/14/14program.htm)
good to top up on this stuff. However readable *Picture to Proton* is, it is no substitute for live lectures. Chemical exchange saturation transfer (CEST) and B1 mapping homogenisation were just two topics that I was particularly interested in. I work at the Institute of Nuclear Medicine at UCLH, the only place in the UK (as of June 2014) that has a simultaneous hybrid PET/MRI scanner, so on hearing the words ‘they can detect endogenous species of interest or a new range of contrast agents that will compliment those in nuclear medicine’, I had to check it out. CEST is the technique used to ‘label’ protons in a specific functional molecular group with long T2 relaxation times that will then exchange with water protons, providing a means to follow, for instance, the metabolic pathway of a particular molecule. We already have a research theme at UCL to better understand the physics underlying the technique. Penny Gowland (Nottingham University) gave a very good tutorial on the technique, on which I can base further reading. The afternoon sessions came under the umbrella of ‘Electromagnetic fields in MRI: from theory to practice’. Quantitative MRI is on the up but in order for the numbers to be correct you have to have a very stable, homogeneous static field and applied fields. I was particularly interested in what the speakers had to say about applied RF homogeneity as I’m currently struggling with fast convenient ways of obtaining this for a whole-body T1 mapping project that I’m working on. Obtaining the same RF field across the large fields of view needed for whole-body imaging is challenging.

**Whole-body MRI**

Whole-body MRI and clinical cancer MRI were scheduled for the Sunday afternoon. My background is in neuroimaging so exposure to whole-body imaging in order to support the oncology programme on the PET/MRI scanner at UCLH is a must for me. I swapped back and forth between whole-body imaging and clinical case-based discussions.

The issue with whole-body MRI is speed. It takes an hour to do a full whole-body scan which typically includes four to five fields of view covering the body from head to mid-thigh with several MR sequences, including T1W dual echo images, T2 accelerated acquisitions and diffusion weighted images with free breathing. All of the major manufacturers are committed to providing faster and faster imaging, particularly of the abdomen, which includes both regular and irregular movements. In particular, new imaging methods such as GRASP (Golden-angle RAdial Sparse Parallel), developed by NYU’s Center for Advanced Imaging Innovation and Research (http://www.youtube.com/watch?v=5FJJBniDuU), and now a work in progress by Siemens, synergistically combines compressed sensing, parallel imaging and golden-angle radial sampling. The technique doesn’t need breath holding and can even provide cines of stomach movement. Not sure what you could use that for but it looks cool! Other presentations included specific oncological applications of MRI such as total-body diffusion-weighted imaging for the assessment of bone metastases. More on this technique can be found in Padhani et al.,1 as well as Blackledge et al.2 Nuclear medicine departments look out! Once this investigation gets down to 30 minutes, you may have some serious competition.

The rest of the conference was as usual – huge and overwhelming at times – but overall an enriching experience (figure 2).

Thank you IPEM for making this possible.

**REFERENCES**


*FIGURE 2*. The conference exhibition space
Mechnotransduction

The conference is held every 4 years. Previous conferences have been in Singapore (2010), Munich (2006), Calgary (2002) and Sapporo (1998). There is significant overlap between biomechanics and bioengineering. In common with bioengineering, the area of biomechanics is growing rapidly. The number attending the WCB has steadily grown from 440 in 1998 to 1,000 in 2014, making the Boston meeting the largest biomechanics conference ever. The meeting had 440 presentations spread over 20 parallel sessions. In this report I will mainly concentrate on those areas that I am interested in: cardiovascular biomechanics, especially patient specific modelling, and mechanotransduction.

Mechanotransduction concerns the conversion of mechanical forces into biology, and vice versa. This area underpins all of biomechanics in both health and disease. In the arterial system, endothelium responds to changes in wall shear stress (WSS) and it was long thought that this meant WSS was held constant over the entire arterial system (through WSS-induced changes in diameter). This can be referred to as the ‘set-point’ hypothesis. Martin Schwartz (Yale University, CT, USA) provided direct evidence in cultured endothelium that the set-point was different for different endothelial types and that VEGFR3 controls the set-point. It was hypothesised that the variation in mean WSS in different parts of the arterial system might be explained by endothelium in different arteries having different set-points for WSS. There are many potential mechanosensors and the details of these are generally poorly understood. A number of different mechanosensors were discussed. Michael Sheetz (Mechanobiology Institute, Singapore) and Sean Sun (Johns Hopkins University, MD, USA) described tension within the cell membrane controlled by cell motility, membrane rescaling and cell signalling, with impacts on motility and trafficking. Donald Ingber (Wyss Institute, Boston, MA, USA) described his long-standing work on the role of the cell as a tensegrity system in which cell shape is determined by tensions within the cytoskeleton, with connections to other cells effected through adhesion sites where the cytoskeleton connects with cell membrane.

Patient-specific modelling (PSM) involves integration of 3D imaging with computational modelling, either finite element methods to estimate stress within tissues or computational fluid dynamics to estimate flow field data and wall shear stresses in vessels. The output in both cases is forces on tissues and the interest is in the prediction of clinical events such as aneurysm rupture. A key area is rupture prediction of aneurysms and there were workshops for abdominal aortic aneurysms (AAAs) and cerebral aneurysms (CAs). Mark Fillinger (Dartmouth Hitchcock Medical Center, NH, USA) gave a review of AAA biomechanics. He mentioned that the first papers describing methodology for wall stress estimation in AAA were undertaken in 2000, and the first clinical studies were undertaken in 2002 (by Fillinger). During the intervening 12 years there has been considerable work on development of appropriate constitutive models (describing stress–strain behaviour) and the creation of workflows suitable for clinical use. However, Fillinger commented that there is still no move to adopt PSM in clinical practice for rupture prediction. It was interesting that many of the talks in the AAA workshop followed these themes, describing workflows (Tim McGloughlin, University of Limerick, Ireland; Seungik Baek, Michigan State University, MI, USA), constitutive model development (Samarth Raut, University of Texas at Austin, TX, USA) and inclusion of anisotropic data from gated CT (Anthony Callanan, University of Limerick, Ireland).

The growth of AAA and of thrombus within AAA is related to inflammation and to the haemodynamic environment. Shawn Shadden (University of California Berkeley, CA, USA) presented MRI and modelling work showing vortex formation in AAA and correlation of thrombus thickness with oscillatory shear index. I presented our work on simulation of monocyte deposition (leading to inflammation) in which we demonstrated that deposition is driven by vortex impact on the distal wall of the AAA. I also presented work on correlation of wall stress with MRI-USPIO data. USPIO (ultrasmall paramagnetic iron oxide) particles have been shown to concentrate in regions of inflammation. Focal inflammation is thought to be predictive of future rupture. We showed in 10 patients that there is no...
correlation between the location of peak wall stress and peak UPSIO uptake (figure 1), which is surprising since other groups have shown correlations between peak wall stress and PET-FDG uptake (another marker of inflammation). There were, however, correlations in all patients between UPSIO uptake around the lumen and wall stress, so a significant component of the luminal uptake of UPSIOs is in fact true inflammation.

In cerebral aneurysms, several presentations (David Steinman, University of Toronto, Canada; Juan Cebal, George Mason University, VA, USA; Hui Meng, University at Buffalo, NY, USA) emphasised the correlation between flow instability and aneurysm rupture, with aneurysms at low risk of rupture having stable flow patterns. Quantitative indices of instability which demonstrated a significant difference between rupture and non-rupture were oscillatory index, WSS difference between rupture and non-rupture instability which demonstrated a significant index between rupture and non-rupture instability which demonstrated a significant difference between rupture and non-rupture. 

**Patient-specific modelling**

For my area of patient-specific modelling, it was significant that much of the work presented was still concerned with methodology development and especially on variations on output depending on the constitutive model. There were almost no clinical studies presented. In a private discussion, a senior international figure voiced the opinion that he feared that stress estimation for rupture prediction in AAA would never be any use because of the problem of variability of data output and the lack of knowledge of key material properties in the individual patient. This is a comment that could be made for much of patient-specific modelling and it is unclear whether this will in fact be a major obstacle in clinical application. A more hopeful viewpoint was expressed by Charles Taylor, CEO of Heartflow (Redwood, CA, USA), formerly of Stanford University and one of the early proponents of patient-specific modelling. Professor Taylor gave a plenary lecture in which he described the work at Heartflow on evaluation of fractional flow reserve (FFR) in coronary arteries using a modelling approach. He described how FFR measured invasively is widely regarded as the most accurate method for assessment of coronary disease and for helping decide which treatment is needed, and the great advantage of his methodology is its non-invasiveness. Heartflow runs a service approach in which they take data from the hospital, undertake the simulations and send these back to the hospital. One eye-watering figure was the $10,000 per patient it costs to undertake these simulations. Professor Taylor talked of thousands of patients analysed to date, which translates into tens of millions of dollars, and this is even before the technique has been approved in the USA.

**Modelling for simulation**

While it was not of immediate interest in my research, it was clear that there has been significant progress in the use of modelling for simulation of vascular prosthesis placement, such as stent deployment (Liam Morris, Galway Mayo Institute of Technology, Ireland; Claire Conway, Massachusetts Institute of Technology, MA, USA). Some of the videos of simulations were indistinguishable from deployment of real stents imaged using fluoroscopy in patients. These techniques could be used to optimise selection of stents for the individual patient, and presentations described this. However, recent FDA (Food and Drug Administration) regulations concerning medical device development allow for validation using computational modelling and it was clear that this was driving the work on vascular prosthetic simulation. Indeed, there was a session devoted to modelling and regulatory issues, a sign of the move of modelling from the lab into clinical practice. Xiangyi Liu (Dassault Systemes Simulia, Providence, RI, USA) and Tina Morrison (FDA, Silver Spring, MD, USA) described the current regulatory framework. It was commented that more often this is to aid development and design optimisation and less often to demonstrate design performance. The relevant FDA committee is ‘Reporting of computational modelling studies in medical device submissions’. It was interesting that the FDA is leading this effort; the FDA is an American organisation, whereas the international standards organisation for electromedical devices is the International Electrotechnical Commission (IEC), so I made a mental note to find out what the IEC is doing in this area.
gallery (there were 440 posters presented per day), I came across a technique to make arteries transparent to allow optical-based flow visualisation experiments (Lars Krenkel, OTH Regensburg, Germany). A few years ago I spent a considerable amount of EPSRC (Engineering and Physical Sciences Research Council) money trying to develop methods for validating ultrasound-based blood velocity measurements in realistic arterial geometries. This was challenging due to lack of availability of transparent phantoms suitable for both optical measurement techniques such as PIV and also suitable for ultrasound. The availability of transparent arteries looked to be a real breakthrough in this area.

The scale and breadth of biomechanics work presented was huge, especially from the American groups which dominated the conference. Professor Ingber described the Wyss Institute which he helped establish in 2005. This has an endowment of $125 million and now has over 300 staff. The institute aims to develop biologically inspired engineering, and Professor Ingber showed examples of organ-on-a-chip devices whose aim was to replace animal testing. I wondered how easy it would be to set up a comparable institute in the UK or even in Europe and how many Nobel prizes might come from this institute in the future.

The 8th World Congress of Biomechanics is in 2018 in Dublin, so it is a meeting I will definitely be attending.

FIGURE 4. Founders’ Memorial, Boston Common. This relief sculpture dates from 1930 when the city celebrated the 300th anniversary of its founding in 1630
SUMMER stands for ‘Software for the Use of Multi-Modality images in External Radiotherapy’, and is a consortium of seven institutions (including industrial, academic and medical partners) from five European countries (figure 1). The aim of the project is to produce a unique software solution that combines multimodality information in a comprehensive way and provides a solution for biological volume delineation, based on co-registration of anatomical and functional information present in different imaging modalities (figure 2). More details on the project can be found on the consortium website (http://summer-project.eu).

One of the aims of SUMMER is to contribute to cross-disciplinary research, and to provide common workshops and collaborations of training and education. Within these objectives, the SUMMER consortium organises an annual summer school which this year took place in Delft (The Netherlands) in the Faculty of Industrial Design Engineering of the Delft University of Technology (figure 3).

Models based on radiomics

In total, the school had approximately 40 participants, comprising PhD and post-doctoral fellows, group leaders and clinicians. The programme included lectures on several topics relevant to multimodal imaging and radiation therapy, including biological target volume delineation, dose planning, visualisation and ergonomics.

Andre Dekker (MAASTRO, Maastricht, The Netherlands) opened the workshop, presenting an insightful talk about how we can use machine learning to extract multifactorial personalised prediction models. Poor prediction of outcome raises questions about knowing which patients benefit more from different types of treatments. TNM staging is a good predictor of outcome for surgery, but not as appropriate with regards to radiotherapy (figure 4). Imaging represents only one out of the six variables considered in the holistic prediction models used by doctors (via unidirectional measurement of tumour size). Other important factors such as dose distribution and biological effect are not even considered.

One suggested approach to improve the existing predictive models is based on radiomics (http://www.radiomics.org). Radiomics refers to extracting and analysing large amounts of features from medical imaging data, including computed tomography, positron emission tomography or magnetic resonance imaging. The images and delineations we have been acquiring daily in the clinic can be converted into mineable data, where features can be extracted. Such features include measures of tumour intensity, shape and texture (figure 5). This data can be used to build descriptive and predictive models relating image features to specific tumour signatures, and therefore provide valuable diagnostic, prognostic and/or predictive information. A study conducted at MAASTRO showed that the ability of such models to predict patient outcome was superior to the models currently used in clinical settings.

The speaker also discussed how radiotherapy research needs more clinical trials to provide evidence of more complex treatments and imaging into the treatment pathway. Unfortunately, traditional clinical trials in individualised radiotherapy are a challenge – typically in trials patients are divided into two homogeneous groups, but in personalised medicine each patient is essentially a rare case. Rapid learning can potentially allow for a quick insight into the benefits of individualised treatment approaches compared to conventional clinical trials.

Minimal invasion

Image analysis nowadays plays a major role in minimally invasive interventions, as presented by Wiro Niessen (Erasmus Cancer Institute, Rotterdam, The Netherlands). In minimally invasive interventions the procedures are performed through small incisions, allowing for faster post-operative recovery with reduced probability of complications. In such procedures the surgeon has very limited visualisation, and so image registration and tracking are necessary to allow navigation. One of the most common examples is image-guided neurosurgery. With brain patients, deformations of approximately 8 mm are typically found between pre-operative and in-room scans, values which can double after the dura is opened (due to swelling of the brain). The tumour shape can also change considerably. Intra-operative imaging (such as CR and ultrasound) is registered to pre-operative MR scans to allow for navigation during the procedure.

Another example of the clinical success of image guidance is in interventional cardiology applications. CT imaging provides contrast of blocked heart vessels, information that is not visible with in-room 2D x-ray imaging systems but is crucial for the success of the intervention. By delineating the coronary arteries in the pre-operative scan, and using 2D/3D registration for navigation, it is possible to achieve an accuracy of 1.4 mm in registering the arteries (figure 6). An even more exciting application is to predict the cardiac motion using motion models, thus removing the need to acquire 4D CT scans for every patient (reducing the clinical cost of the procedure and the radiation dose delivered to the patient).

To conclude, the speaker discussed applications in hyperthermia treatment planning (HTP). Hyperthermia consists of locally heating a tumour to increase the success of subsequent radiotherapy. However, HTP is very time consuming, and automatic segmentation algorithms can be used to considerably reduce the treatment planning time.

Nanoparticle technology

Non-rigid image registration is increasingly becoming more and more important in radiotherapy. Eliana Vasquez (Erasmus Cancer Institute, Rotterdam, The Netherlands) presented state-of-art applications such as assessing organ motion and deformation, contour propagation and dose accumulation. Image registration is the process of aligning different sets of data onto a single co-ordinate system. A radiotherapy treatment is planned on a ‘snapshot’ of the patient, but is actually delivered daily over several weeks during which the patient’s anatomy can change (such as variations in weight or tumour size). Dealing with deformation is crucial to assure treatment success, where deformable registration can provide a solution to this...
FIGURE 1. The SUMMER consortium consists of a collaboration of seven institutions from five European countries aiming to develop a unique software solution for multimodal imaging in cancer treatment.

FIGURE 2. Researchers from the SUMMER consortium are developing software solutions to use multimodal imaging for biological volume delineation. Reproduced with permission from Miguel Nunes.

FIGURE 3. View of Delft historic centre and canals.

FIGURE 4. Traditional outcome prediction models are known for poor prediction. Studies show that doctors correctly predict outcome in approximately 50–60 per cent of cases. Reproduced with permission from Dr Andre Dekker.

FIGURE 5. Routinely acquired CTs and delineations can be converted into mineable data. Diverse features can be extracted to identify the tumour signature. Reproduced with permission from Dr Andre Dekker.

FIGURE 6. In minimally invasive interventions the surgeon has very limited visualisation. Registration and tracking can be used to integrate all available data and facilitate navigation. Reproduced with permission from Dr Wiro Niessen.
breakthrough of cancer treatment and nanoparticle technology will be the Northern Ireland) talked about how interpreting the results obtained. Here, two types of applications are relevant: summing dose delivered by different treatment modalities (for example, radiotherapy and hyperthermia), or dose delivered over several radiotherapy fractions. The true dose accumulated is of particular importance for treatment adaptation. However, until insight is gained on how uncertainties in the registration affect the accumulated dose distributions, the utmost care is necessary when interpreting the results obtained.

Suneil Jain (Queen’s University Belfast, Northern Ireland) talked about how nanoparticle technology will be the breakthrough of cancer treatment and personalised medicine. In nanotechnology, molecular-sized particles are used to deliver drugs, heat, light or other substances to specific parts of the body. Progress in nanomedical research offers the potential to specifically target metal nanoparticles to tumour cells. Gold nanoparticles are of particular interest, due to their small size, large surface to volume ratio, biocompatibility and relative ease of manufacture. Currently, they are being investigated for a plethora of applications, including diagnosis, drug delivery and laser therapy. Existing drugs can be modified to improve pharmacokinetics, and therefore increasing dose delivery to target volumes whilst reducing non-specific side effects. Considering therapeutic applications, a laser producing non-ionising electromagnetic radiation can be applied to the volumes of interest. Conversion to heat energy occurs in metal nanoparticles (owing to electron excitation and relaxation) delivering energy to highly localised regions. One of the main difficulties in translating such compounds to the clinic is the difficulty in characterising them and ensuring reproducibility in production, but biological issues such as retention months after administration are also being studied.

The SUMMER meeting provided a unique opportunity to meet with multidisciplinary researchers and clinicians to discuss how multimodal imaging can be further used to improve patient outcome. Technical, software and scientific needs of cancer therapy in the next few years were discussed. The introduction of further individualised treatments, comprehensive software solutions and improving our ability to predict patient response and outcome (using additional functional information) are the key areas of research in this field. The event was overall very enjoyable and gathered a very enthusiastic group. It was well organised, both in terms of lectures provided and leisure activities arranged. I came away very motivated to continue doing research in this area and thoroughly recommend others to attend the 2015 SUMMER school, which will take place in Freiburg.

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My submission for a poster presentation was accepted for this year’s Joint Annual Meeting of the International Society for Magnetic Resonance in Medicine and the European Society for Magnetic Resonance in Medicine and Biology (ISMRM–ESMRMB; figure 1). I was able to attend the meeting, held in Milan from 10th to 16th May, with the support of an IPEM travel bursary. ISMRM is the largest annual meeting of the international MRI community and brings together physicists and clinicians from academia, industry and healthcare. This provides the perfect opportunity to make new contacts, to forge potential new collaborations and of course to learn about new products and techniques.

Milan provided a stylish backdrop to this year’s conference, from the dramatic form of the cathedral (figure 2) rising over the aptly titled Piazza del Duomo to the exquisitely dressed Milanese on their way to the supermarket. Fittingly, this year’s conference theme was ‘Fashioning MR to improve global healthcare’. Whilst the usual brands of Gucci, Armani and Versace were showcased in the extravagant splendour of the local shopping centres (figure 3), this conference staged the advent of techniques such as PET/MRI and compressed sensing. Of particular relevance to my current work were fetal imaging and magnetic resonance spectroscopy (MRS). Here is a summary of some of the education and scientific sessions that I attended.

**PET/MRI**

PET/MRI featured prominently in the conference itinerary and I attended an overview of the technical aspects and challenges of combining these modalities given by Harald Quick (Siemens Medical, Erlangen, Germany). The Biograph mMR (Siemens Healthcare Sector, Erlangen, Germany) is a fully integrated whole-body PET/MRI system comprising both a 3T MR system (maximum gradient strength of 45 mT/m, maximum slew rate 200 mT/m/ms) and PET detection. Professor Quick discussed how an important step in combining these modalities was in replacing the photomultiplier tubes conventionally used in PET scanners with detector units comprised of lutetium oxyorthosilicate (LSO) arrays and avalanche photo diodes (APD). Photomultipliers are bulky and crucially could not be placed at the isocentre of the MR system as their operation would be adversely affected by the high field strength environment. The LSO–APD detector units are much smaller, are robust within the high field strengths and so are ideal for this purpose. One PET detector ring is comprised of 56 LSO–APD detector units and a complete PET detector unit is comprised of eight rings.

Professor Quick also highlighted the continuing hardware challenges and research opportunities of PET/MRI. A major area of continuing development is in the generation of MR-based attenuation correction maps. These are vital to allow the quantification of PET tracer activity once it is distributed in the body. The manufacturer has pre-generated CT attenuation correction maps of the scanner hardware (e.g. patient table, spine array coil, head coil). However, human soft tissue maps are produced using MRI. This uses a 3D Dixon-volume interpolated breath-hold examination (3D Dixon-VIBE) sequence which produces two sets of images; the first where water and fat are ‘in-phase’ and the second where they are ‘out-of-phase’. This allows the segmentation of four different types of signal; from fat, muscle, lung and air. As bone produces no signal using this sequence, the segmentation of bone is currently omitted. This leads to the underestimation of attenuation due to bone and errors in quantification of activity in lesions close to bone.’

Ultrasound echo time (UTE) sequences, with a very short T2* value, allow bone to be visualised. A combination of Dixon and UTE sequences has been used to generate soft tissue attenuation coefficient maps of the
head and neck. As UTE sequences are currently only practical over small fields of view (FOV), this technique has not yet been applied to body imaging but is currently an active area of research.

Another problem with MR-based attenuation correction is that the patient’s arms are often outside the available FOV. This could have significant consequences for PET quantification, and new techniques are emerging to address this. One technique being used to provide an extension to the useable MRI FOV is homogenisation using gradient enhancement (HUGE). This compensates for inhomogeneities in the static magnetic field and gradient non-linearities by using measurements of these to produce a patient-optimised readout gradient field. This can be applied locally to a particular region of interest, for example the patient’s arms, and typically produces a FOV extension of 10 cm.

As expected, there were many presentations comparing the accuracy of PET/MRI with PET/CT, mainly in oncology applications. For example, Amy Melsaether (NYU School of Medicine, New York, USA) presented a comparison of $^{18}$F-FDG PET/MRI and $^{18}$F-FDG PET/CT for evaluation of metastatic breast cancer in 50 patients. Two radiologists reported the number of metastases observed from PET/MRI and PET/CT images in liver, lung, bone, brain, axillary node and other nodes. The number of breast malignancies was also recorded. This study used the unblinded review of all prior and follow-up examinations and pathology reports as the reference standard. The numbers of subjects with metastases in each organ, as reviewed by two readers, are shown in figure 4. These are shown alongside the reference standard (RS) results. PET/MRI detected brain (n = 5), liver (n = 2) and bone (n = 1) metastases and breast malignancies (n = 5) in 11 patients that were not observed by either reader on PET/CT.

**Fetal and placenta imaging and MRS**

I also attended sessions relating to fetal and neonate imaging as this is relevant to my current work. One presentation of particular interest, given by Uday Krishnamurthy (Wayne State University, Detroit, MI, USA) on behalf of the listed speaker Pavan Jella, was on the topic of blood oxygenation measurements in the fetal brain. There are currently limited methods for assessing hypoxic ischemic brain injury in the fetus and diagnosis is often delayed until after delivery. The technique described by this group uses susceptibility-weighted imaging and the principles of susceptometry to estimate fetal blood oxygenation in the sagittal sinus of the fetus. Using a gradient echo sequence, the phase difference between a tissue of interest and its surroundings gives a direct measure of the perturbation of the magnetic field within that tissue. Also, there is a difference in the susceptibility of the paramagnetic deoxyhaemoglobin present in venous blood compared to surrounding tissues, which depends on the concentration of deoxyhaemoglobin present in the vein. These parameters allow estimation of the cerebral venous oxygen saturation and this technique can be used for assessment as early as 19 weeks gestation up to term. Changes in cerebral venous oxygen saturation could indicate a decrease in arterial oxygen supply due to cerebral hypoxic-ischemia and could support clinical management following delivery. This study measured the fetal oxygen saturation in 13 healthy pregnancies in the second trimester and 14 in the third trimester. It was found that oxygen saturation across the second and third trimesters is 63.7 ± 10 per cent with no significant differences between these two groups (figure 5).

The presentation by Rui Vasco Simoes (Barcelona Center for Maternal-Fetal and Neonatal Medicine, Barcelona, Spain) focussed on $^1$H MRS in the fetal brain in cases of late-onset intrauterine growth restriction (IUGR). IUGR is a condition that is often due to placental insufficiency. It can result in poor neurodevelopment and at its most extreme can result in stillbirth. In cases of late-onset IUGR, Doppler ultrasound assessment of the umbilical artery remains normal. Therefore, the aim of this study was to identify signatures in the MR spectra that could indicate that this condition is present. Their cohort included 71 singleton pregnancies with late-onset IUGR confirmed by a birth weight of <10th percentile and 65 that were adequate as healthy controls for gestational age. They found that spectra from the IUGR fetal brains had significantly reduced total NAA/choline ratios compared to those of control subjects. This has yet to be validated against neurobehavioral follow-up.
up studies but this finding provides a promising possible identifier of cases of late-onset IUGR.

The poster that I submitted in collaboration with the Centre for Reproductive Health at the University of Edinburgh was also on the topic of $^1$H MRS applied to pregnancies affected by IUGR and placental insufficiency. Although we have also acquired spectra from the fetal brain, the topic of the poster was on its novel application to the placenta in utero. There was much interest in the poster and the discussions I had and the feedback I received were both useful and encouraging.

**Sparse data and compressed sensing**

A common theme that emerged from the fetal and neonate presentations was that of the impact of motion on image and spectral quality. When asked how they dealt with motion, speakers replied that in these instances they simply repeated imaging and MRS studies. Repetition is time consuming and inconvenient, especially in fetal, neonate and paediatric imaging where there is no guarantee that repeated studies will also not be affected by motion.

I had noticed a poster presented by Yong Pang (University of California, San Francisco, CA, USA) in which the technique of compressed sensing had been applied to fetal imaging. This technique involves the application of a non-linear reconstruction algorithm to produce an image from undersampled k-space data, where k-space is the raw data matrix containing the frequency and phase-encoded MR signals necessary to generate MR images. As fewer k-space samples are acquired, the acquisition time is reduced and as a consequence the effects of motion are also reduced. This poster also reported results for the application of interpolated compressed sensing (iCS). This uses the k-space data from neighbouring image slices to compensate for missing k-space data in the target slice. This technique was found to offer an improvement in contrast-to-noise of up to 30 per cent compared to the conventional sparse MRI reconstruction using the same undersampling rate.

As compressed sensing is still a relatively recent application to MRI, there were also many oral presentations on its novel application. The work presented by Joseph Cheng (Stanford University, Stanford, CA, USA) resolved respiratory motion in dynamic contrast-enhanced MRI studies of the abdomen. In particular, this work was concerned with free breathing in paediatric studies, as adequate breath holding is not always possible in this group. They extended the image acquisition space to include an additional respiratory dimension, nresp, and performed respiratory navigation using a custom-designed sequence. They acquired data using variable-density sampling and radial view ordering, and reconstructed the highly undersampled data set using two different models of sparse data. The total variation (TV) penalty was applied to the nresp dimension and the locally low-rank constraint was applied to the dynamic contrast data dimension, nDCE. Data binning in nresp and nDCE provided further constraint on the reconstruction. In a free-breathing 4-year-old patient they found that this approach produced similar contrast dynamics to a reconstruction carried out without resolving respiratory motion. However, image quality was slightly improved with the presented technique.

This conference provided an excellent opportunity to sample the breadth of work currently being carried out in the MRI community. There was also plenty of opportunity to learn about the details of these topics and to engage the experts in discussion. I enjoyed finding out what everyone, in both the academic and commercial worlds of MRI, has been busy doing over the last year. The conference made sure that research projects will be heading in relevant future directions, but just being in Milan made us all a little bit more fashionable!

**REFERENCES**

Welcome to another exciting mix of book reviews and a final one for 2014! I would like to thank our book reviewing team for their contributions to this section. There are five book reviews in this issue where textbook reviews cover the medical physics and the popular science genres. A list of the reviewed titles with reviewers can be found in table 1.

There are a number of new textbooks in the ‘Just Published!’ section, one of which is Practical Radiation Protection in Healthcare. This book provides a practical guide for medical physicists involved with radiation protection in the healthcare environment.

Most of the development of the materials described in the first three sections relates to structures at the atomic scale, so-called nanoparticles with pore sizes at the Angstrom level. The reader requires an extensive knowledge of polymer chemistry to understand the principles of surface chemistry and mechanisms of drug delivery through the barriers of the polymers used and through physiological barriers of the gut, liver or blood vessels and cells. The authors use the term ‘stimuli-responsive smart nanoparticles’ which would control the delivery of drugs to targeted sites or in the other direction, absorb body fluids to detect parameters for diagnostic and measurement purposes. They propose a new term for materials that could be used for either diagnostics or therapy of ‘theranostics’. I doubt if this term would be adopted universally, but it does stress that modifications to these new materials could change their function by ‘tweaking’ these nanoparticles for whatever application the material is targeted, so-called ‘smart’ materials.

I was particularly impressed by the problems of design in the chapter on ‘Nanoparticles for diagnostic and treatment of Alzheimer’s disease’ and overcoming the problems of transferring or breaching the so-called ‘blood–brain barrier’ to target the amyloid plaques which are implicated in the progression of the disease.

The control of degradation is rigorously explored in the chapters dealing with the advantages of translational materials, such as the porous hydrogels used in wound healing. I was very interested to read of the ability of these materials to adjust the mechanical properties relating to the application. A small chapter in this section delve into the possibility of producing tissue-engineered biodegradable scaffolds, the amount of degradation being dependent on the mechanical stimuli, which is a very exciting field that I would have liked to have expanded.

Although it is claimed in the Preface that this book is written for university students and researchers from diverse backgrounds, I believe having read the majority of the scientific aspects of the work that it really expects the reader to have a very thorough knowledge of polymer chemistry at the nanometer level of particle or pore size. This suggests that the book is in fact aimed at researchers in the pharmaceutical industry or academics in pharmaceutical chemistry research rather than researchers into biomaterials.

Professor Julian Minns is a Consultant Clinical Scientist and holds an Honorary Chair in Medical Implant Design, Product Design Research (PDR) Centre at Cardiff Metropolitan University, UK

**TABLE 1**

<table>
<thead>
<tr>
<th>Book title</th>
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<tr>
<td>Advanced Healthcare Materials</td>
<td>Julian Minns</td>
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<tr>
<td>Measurement, Instrumentation and Sensors Handbook</td>
<td>Azzam Taktak</td>
</tr>
<tr>
<td>Electromagnetic Fields, Environment and Health</td>
<td>Glyn Coutts</td>
</tr>
<tr>
<td>Biologically Optimized Radiation Therapy</td>
<td>Keri Haselip</td>
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<tr>
<td>Physics for Clinical Oncology</td>
<td>Usman Lula</td>
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ADVANCED HEALTHCARE MATERIALS
ED ASHUTOSH TIWARI
Publisher: John Wiley & Sons Ltd
ISBN: 978-1-118-77359-8
Pages: 525
Price (publisher’s website): £130
Measurement, Instrumentation and Sensors Handbook

This is the second edition of this very popular book with a blend of revisited material and more up-to-date technology in this fast advancing field. A mixture of styles is adopted in writing this book; from didactic style to the more modern problem-based learning style. The text is backed up by a considerable number of illustrations and practical examples of use in everyday life. Due to the huge amount of material covered, the book is divided into two volumes.

Volume 1

The volume is divided into 10 parts with 96 chapters in total. There are more than 150 authors contributing to this volume and although the editors have done a fantastic job in ensuring a common style, there is inevitably some inconsistency. However, as this is not a book one is likely to read from cover to cover, this does not present a major issue. The volume covers a whole raft of sensors and devices used in various engineering applications including biomedical engineering. At the end of most chapters is a list of vendors and suppliers of the types of sensors discussed within it.

The first part covers the basics of instrumentation and measurements. It starts with the basic definitions of precision and accuracy and how these concepts affect calibration standards. It then very quickly moves on to the more modern trends in technology such as smart sensors, wireless, networked and virtual instruments, giving real-life examples where this technology is used.

The second part delves into physics and engineering principles of measurements of spatial variables such as thickness, distance, height, area, volume, etc. Here, again, there is a good comprehensive coverage of old technologies such as linear variable differential transformer (LVDT) and Hall effect transducers through to new and emerging technologies such as THz and nanoscale scanning probe microscopy. The third part concentrates on the measurement of displacement, starting with the tried and tested technology of potentiometers, capacitive, inductive and piezoelectric sensors which are used in many physiological measurement applications to the more sophisticated laser, ultrasound and optical sensors. Each chapter in the part covers the principles and signal detection and conditioning related to each type of sensor.

Part Four covers sensor technology for the measurement of mechanical variables such as force, pressure, strain, etc. Here, again, there is a comprehensive review of the well-established technologies such as strain gauges and Wheatstone bridges, load cells, accelerometers, etc. In addition, this part introduces more modern technologies such as tactile sensing, which is used widely in robotics. There is a significant chapter on accelerometers, highlighting their advantages of being able to derive force, distance and velocity and their numerous applications.

Part Five is on acoustics and has two chapters only; acoustic measurement and ultrasound measurement. Making sound pressure level, intensity and frequency measurements is very important in audiology whereas ultrasound measurements have numerous applications in the medical field. Part Six deals with flow and velocity measurements with a wide array of sensor technologies covered. Part Seven concentrates on temperature measurements describing the various types of sensors and techniques used in measuring temperature, such as thermocouples, thermistors and various other types of sensor. It finishes with a couple of chapters on thermal imaging and calorimetry. Part Eight is dedicated to measuring radiation and dosimetry.

The final two parts in this volume cover the topics of wireless instrumentation and human factor engineering. Both of these have huge significance in biomedical applications. Wireless sensors are gaining much attention in physiological measurement due to the ultimate electrical safety environment and practicality they offer, whilst human factor engineering is a crucial part of the design of medical equipment.

Volume 2

Volume 2 of this book is also divided into 10 parts with 98 chapters in total. There are more than 180 authors listed. As with Volume 1, this volume is more of a reference book than a textbook. The editors emphasise this fact in the Preface by suggesting that the best way to use this book is once you know what type of variable you want to measure, then you should skip to the relevant chapter(s) that describe the different methods of making the measurement. Once again, many chapters list a number of vendors who can be contacted for more information.

Part One of this volume covers generic aspects of sensors, sensor technology, the principles of smart sensor technology, energy harvesting for sensors and much more. The next few parts each cover sensors for a particular type of variable, including electrical, electromagnetic, time and frequency, optical, chemical, medical/biomedical and environmental.

Part Eight covers the types of sensors used for medical, biomedical and health applications. There is a lot of material on wireless sensors and network standards used in healthcare. This part covers typical applications of the technology in healthcare, such as home monitoring, assisted living and sports applications. Chapter 63 classifies wireless sensors into three main categories: video sensors, wearable sensors and object-usage-based sensors. The first two categories are obvious from the name. The third includes sensors fitted to appliances and/or furniture such as cookers, etc.
Electromagnetic Fields, Environment and Health

This small book is intended for anyone who may have concerns about the health effects of exposure to non-ionising radiation encountered in all aspects of modern life. It seeks to provide an accurate summary of the state of our understanding, together with pointers to further information. The first chapter gives a brief introduction to the physics of electromagnetic radiation. There follow chapters on static magnetic fields, electric fields and then eight chapters working along the spectrum from extremely low-frequency fields to UV and lasers. Each chapter follows a similar layout addressing the basic physics, sources, interactions with living matter, exposure limit values, and precautions and protection. Inevitably, there is some variation in quality. The chapter on UV radiation is particularly informative, and the conclusions drawn on the contentious issue of the health effects of wireless communication is a model of clarity. On the other hand, the brief chapter on radiofrequency identification systems (RFID) does very little to inform the reader.

As a hostage to the structured layout of the book, magnetic resonance imaging (MRI) is lumped in with static electric and magnetic fields, despite clearly also requiring time varying magnetic fields in the kilohertz range as well as RF fields. Furthermore, publication was prior to the adoption of the EU Physical Agents Directive (Electromagnetic Fields) 2013/35/EU, which repealed the earlier 2004/40/EU referred to in this book.

Due to come in to law in the member states in 2016, in setting limits on workers’ exposure to electromagnetic fields, this has relevance across the field but particularly as the directive now contains a derogation, in Article 10 (a), for MRI in the health sector. Further guidance on implementation is due to be published soon.

This is the English version of the French original, and the reader will regularly trip over oddities in the translation, which also extend to a not particularly helpful glossary: ‘Palpebral’, as in ‘palpebral reflex’, is marked as being in the glossary where it does not appear, but ‘blink’ – apparently ‘of the eyelid’ – does. There is also an instance of archaic and inappropriate terms being used to describe skin colouring.

In brief, this book’s value lies in bringing together in one place an overview of our current understanding of the health impact of non-ionising radiation in the environment, but for any depth the reader will need to turn to the references.

Dr Glyn Coutts is a Clinical Scientist based in the Medical Physics & Engineering Department, The Christie NHS Foundation Trust, Manchester, UK.

Biologically Optimized Radiation Therapy

Biological optimisation is the holy grail of radiotherapy – the ability to tailor a treatment such that it has the highest probability to cure, and the
lowest to cause harm. This is an ambitious book that not only discusses biological optimisation from the modern standpoint, but also works through the entire history of radiotherapy development and treatment machine design. There are topics on what you’d expect, such as Bio-Art (biologically optimised adaptive radiotherapy) and molecular imaging. But there is a lot of unexpected work in here, including huge sections on the editor’s pet projects: scanned pencil-photon beams and high-energy light ions, with whole chapters dedicated to the designs of these specialised treatment machines. They are not confined to specific chapters either; references can be found littered throughout the text at every opportunity and it begins to feel like a persistent sales pitch. It baffled me why such an in-depth look at these was required when they are relevant to so few clinics.

I was also confused as to which era this book was written in. As an example, although it was published in 2014, one section refers to ‘new developments’ referenced in a paper published in 1998. The back cover states it is a compilation of previously unpublished material, which may explain why it is unstructured and so often seems stuck in the past.

The writing style is not very accessible and it is not clear who the target audience is. The text jumps around from the most basic principles to the most complex; in one example explaining what an isodose line is before jumping into a mathematical analysis of plan optimisation. Mathematical terminology spills into the language even when trying to describe things in simple English, which for me resulted in a style that is not very engaging and quickly became tiresome to read.

On nearly every page is a glossy, brightly coloured diagram... however, most are so poorly designed they are almost unintelligible. Masses of text and symbols are all piled into each confused illustration, many of which have been so poorly formatted they can’t be read.

In all, this book unfortunately isn’t what I expected. It has far too much bias towards the author’s own projects and attempts to cover far too many topics. It is hard to recommend it to anyone who doesn’t have a particular interest in scanned photon beams or light ion therapy, which is a shame because there is undoubtedly a lot of valuable scientific work packed into its many pages – I’m just not sure it should all be in one book.

Keri Haselip is a Principal Clinical Scientist based at the Medical Physics Department, Queen Alexandra Hospital, Portsmouth, UK

BIOLOGICALLY OPTIMIZED RADIATION THERAPY
ANDERS BRAHME (editor)
Publisher: World Scientific
Format: Hardback (also available as an ebook)
Pages: 688
Price: £73

The writing style is not very engaging and quickly became tiresome to read.

The book has been written with the trainee in mind, with a great consistency between chapters and minimal repetition. Each chapter is broken down into various sections and subsections which help the reader focus on individual topics. There are plenty of non-colour illustrations scattered throughout the book with a few pages in the centre (‘colour plate section’), reproducing a select few in colour. Concepts are well explained, sometimes using analogy whilst at other times, clinical examples. Some topics are more descriptive than others and there is ample cross referencing between chapters. The book is relatively
up-to-date, touching upon adaptive radiotherapy, VMAT and tomotherapy.

Although the following issues can easily be ironed out during a revision, I felt they should be afforded a mention. There are a significant number of typos throughout. Occasionally, there is a lack of referencing in the main body of text to illustrations/tables in the same chapter. In the examples in Cases 1 and 2, there are errors in calculations. Moreover, the elongated field size given in Case 1 is not an example of moderate elongation as described in BJR Supplement 17. The book does have a UK slant to it. It would be useful to have a page on abbreviations and an end-of-chapter summary of the main learning points. There is unevenness in the number of pages between chapters and the UK/US English language dictionary is used interchangeably. For trainees, it would be useful to have key terms highlighted in bold and more boxed descriptions. More importantly, it would be ideal to have references to some of the work included in the book.

Just Published!

Advanced Biomaterials and Biodevices by Ashutosh Tiwari and Anis N Nordin (John Wiley & Sons) focuses on the emerging area of biomaterials and biodevices that incorporates therapeutic agents, molecular targeting and diagnostic imaging capabilities. The book is written for a large and broad readership including researchers and university graduate students from diverse backgrounds.

Mathematical Oncology 2013 by Alberto d’Onofrio and Alberto Gandolfi (Birkhäuser) highlights the work of world-class research teams and explores how different researchers approach the same problem in various ways. It will appeal to graduate students and researchers in biomathematics, computational and theoretical biology, biophysics and bioengineering.

Practical Radiation Protection in Healthcare by Colin J. Martin and David G. Sutton (OUP) provides a practical guide for medical physicists and others involved with radiation protection in the healthcare environment. The guidance is based on principles set out in current recommendations of the International Commission for Radiological Protection and methods developed by a variety of professional bodies.

Diagnostics Radiology Physics: A Handbook for Teachers and Students by D.R. Dance, S. Chrostofides, A.D.A. Maidment, I.D. McLean and K.H. Ng (IAEA) successfully fills the gap in the teaching material for medical radiation physics in imaging, providing, in a single volume, the largest possible coverage available today.

All About Science by Maria Burguete and Lui Lam (World Scientific) aims to clear up confusion and misconception concerning science. It presents new developments in the philosophy, history, sociology and communication of science. It is written by prominent scholars including the Nobel laureate Robin Warren, sociologist Harry Collins and physicist-turned-historian Dietrich Stauffer.

Nonlinear Approaches in Engineering Applications by Lining Dai and Reza N Jazar (Springer) focuses on the latest applications of non-linear approaches in different disciplines of engineering and to a range of scientific problems. For each selected topic, detailed concept development, derivations and relevant knowledge are provided for the convenience of the readers.

Particle Accelerators: From Big Bang Physics to Hadron Therapy by Ugo Amaldi (Springer). There are three kinds of physicists, namely the machine builders, the experimental physicists and the theoretical physicists – without the machine builders we would not get into this small-scale region of space. The author’s motto is ‘Physics is beautiful and useful’ – this is a must-read introduction to the frontier of modern technology.

Applications of Modern Physics in Medicine by Mark Strikman, Kevork Spartalian and Milton W. Cole (Princeton University Press) describes the fundamental physical principles underlying technological advances, emphasising their applications to the practice of modern medicine.

Nuclear Iran by Jeremy Bernstein (Harvard University Press) brings the author’s knowledge as a physicist to bear on issues, offering elucidation of the scientific principles and technical hurdles involved in creating nuclear reactors and bombs. It guides readers through an intricate maze of science and secrecy that lies at the heart of Iran’s nuclear ambitions.

CERN: How We Found the Higgs Boson by Michael Kruse (World Scientific) provides a broad look at the fascinating history of CERN and the physicists working in different areas at CERN who were active in the discovery of the Higgs Boson. This invaluable book will capture the interest of the curious reader, telling the story of one of the greatest scientific endeavours ever.

Gravity by Jason Chin (Roaring Brook Press) explores the wild possibilities of a world without gravity, combining science and illustrative art. What keeps objects from floating out of your hand? What if your feet drifted away from the ground? What stops everything from floating into space? The answer is gravity.

A must-have addition to a departmental library

Overall, this textbook is great value for money, and a must-have addition to a departmental library. The authors are expecting to update the online version of the book based on comments provided in this review. I would very highly recommend this to anyone interested in, or training in, the field of radiation oncology.

Mr Usman Lula is a Principal Clinical Scientist working in Treatment Planning at Queen Elizabeth University Hospitals Birmingham NHS Foundation Trust. His role supports R&D and Clinical Trials.
Clinical Technologist News Editor

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Learning takes place predominantly in the workplace through completion of portfolios, web-based activities, practical and theoretical assessments using ‘Moodle’ which is an open source learning platform. All course materials, study support and resources are available online.

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<td>8</td>
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EBME Manager, West Midlands, September 2014

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PART 4: Taking to the international stage

Stanley Salmons continues his historical feature series with events leading to the formation of national and international societies

Through diverse paths individual engineers emerged from their war-time roles and found their way into medical or biological research in companies, universities, research institutions and hospitals. The opportunities for doing so were often created by researchers who were keen to apply techniques developed during the war but lacked the time or expertise themselves to design and construct the necessary instrumentation. Funds usually came from external sources, such as the Paul Instrument Fund of the Royal Society, and these would be used to support work on a specific project. This would be pursued in isolation, for in the 1950s there was no society through which they could meet and exchange ideas. Nor was there a journal dedicated exclusively to biomedical engineering; they published in the journals of the time. The Journal of Scientific Instruments was considered the prestige publication for reporting new work; many relevant articles appeared in Electronic Engineering and Wireless World and some in the journals of the Institution of Electrical Engineers and British Institution of Radio Engineers. Those engaged in physiology could demonstrate their work at meetings of the Physiological Society if they were introduced by a member. The Physical Society held an annual exhibition at Imperial College London, and it was prestigious to have work accepted for this event and for the Royal Society’s Annual Conversazione.

By 1953 the Institute of Radio Engineers in the USA had formed its Professional Group on Medical Electronics and began to hold annual symposia in conjunction with the American Institute of Electrical Engineers and the Instrument Society of America. Whilst conceivably of help to workers in the USA, it had a paucity of opportunities for communication between those working in medical electronics. The opportunities for doing so were often created by researchers who were keen to apply techniques developed during the war but lacked the time or expertise themselves to design and construct the necessary instrumentation. Funds usually came from external sources, such as the Paul Instrument Fund of the Royal Society, and these would be used to support work on a specific project. This would be pursued in isolation, for in the 1950s there was no society through which they could meet and exchange ideas. Nor was there a journal dedicated exclusively to biomedical engineering; they published in the journals of the time. The Journal of Scientific Instruments was considered the prestige publication for reporting new work; many relevant articles appeared in Electronic Engineering and Wireless World and some in the journals of the Institution of Electrical Engineers and British Institution of Radio Engineers. Those engaged in physiology could demonstrate their work at meetings of the Physiological Society if they were introduced by a member. The Physical Society held an annual exhibition at Imperial College London, and it was prestigious to have work accepted for this event and for the Royal Society’s Annual Conversazione.

On his retirement from the Radio Corporation of America, the television pioneer V.K. Zworykin went to the Rockefeller Institute for Medical Research in New York where, together with the physiologist Detlev Bronk, he was instrumental in establishing a Medical Electronics Center in 1955. Zworykin recognised that the paucity of opportunities for communication between those working in medical electronics represented an obstacle to the further development of the field, and set out to improve matters. He travelled to several countries, where his perceptions were reinforced by meetings with people who he found were working independently on similar problems. He decided there was a need to form an international organisation to foster the application of electronics to medicine. The following note appeared in the August 1957 issue of Wireless World:

Medical Electronics: An international organisation to foster the application of electronics to medicine is being formed by Dr V.K. Zworykin, the well-known American pioneer in electronic television. Interviewed recently by Wireless World in Paris, Dr Zworykin said he felt that electronics should be applied more directly than it has been to the benefit of humanity. Already he has been instrumental in establishing a Medical Electronics Center in the Rockefeller Institute for Medical Research in New York. The aim here is to develop new electronic techniques for the medical world without any form of commercial exploitation, and already several devices have been produced on this basis. Dr Zworykin has also composed a bibliography of medical electronics literature. He hopes to organise an international conference on the subject, possibly at the time of the 1958 Brussels Exhibition.

In response to this announcement, Reg George wrote to Zworykin to express interest, and the latter’s reply, dated 30th September 1957, reveals his thinking:

Dear Mr George, Electronic techniques are coming to play an increasingly important role in medical research and practice. Nevertheless, all of us who have been closely associated with recent advances in electronics are well aware that the contributions of this new art in medicine and the life sciences could well be far more substantial than they are today. The main barrier to the full realization of the potentialities of “medical electronics” appears to be a lack of communication, both between electronic engineers and life scientists and between workers in the same field in different parts of the world.

After describing what had been done in the USA, and at the Rockefeller Center in particular, he continued:

I have been impressed with the need of extending the activities beyond national frontiers.
The Paris conferences

An announcement and call for papers for the conference was published in November 1957. It would be held in Paris in the Faculty of Medicine from 26th to 28th June 1958. Zworykin asked the Institution of Electrical Engineers to suggest four or five people to represent the UK. In the event, 10 attended: C.N. Smyth, B. Shackel, R.E. George, P. Bauwens, A.S. Velate, W.J. Perkins, R.C.G. Williams, S.L. Sherwood, S.N. Pocock and T.E. Ival. These joined attendees from France, the USA, Italy, Sweden, Switzerland and Germany. In addition to discussions and presentations of 10-minute scientific communications, the meeting agreed to hold a further conference the following year; C.N. Smyth and B. Shackel were among those elected to the Interim Committee.

The ten UK delegates met informally on 30th July 1958 to review the draft proposals approved at the conference a month earlier. They envisaged a British Group for Medical Electronics, to act as a focus for relevant work within organisations such as the Royal Colleges, the Medical Research Council, the Institute of Electrical Engineers, the British Institute of Radio Engineers and the Physiological and EEG Societies. This group, whose members would include otherwise unaffiliated workers, would function as a learned society, arranging its own scientific meetings, and affiliated to the International Group that was clearly emerging. They envisaged a British Society, and into this the members elected would begin to be affiliated. The idea was that, under the auspices of the International Group, the British Society would be formed in due course.

They foresaw that the British Society would be seen as a learned society, including its own scientific meetings, and that it would form a focal point of the International Group. They envisaged that the British Society would be formed in due course. They foresaw that the British Society would be seen as a learned society, including its own scientific meetings, and that it would form a focal point of the International Group.

The British Society was envisaged by its founding members as the focal point of the International Group. It was envisaged that the British Society would be formed in due course. It was envisaged that the British Society would be seen as a learned society, including its own scientific meetings, and that it would form a focal point of the International Group.

Formation of a British society

Often it is only after national societies have been set up that an umbrella organisation is created with a view to seeking a more international voice. In this instance it was the reverse. The role of the IFME was envisaged at the outset as a federation of national societies or groups rather than of individual members. To this end a Congress or General Assembly. The 40 or so delegates from the UK resolved to meet again soon after their return to see what could be arranged at a national level, and they elected Professor Ronald Woolmer and Dr Alfred Nightingale as their UK representatives.

Alfred Nightingale

Alfred Nightingale was educated at St Albans Grammar School, where his father was physics master and author of the widely used textbook Heat, Light and Sound. After graduating from Emmanuel College, Cambridge in 1943, Alfred was seconded to the Admiralty as a member of a research team working on electronic underwater sound devices. In 1947 he joined the Medical Physics Department of the Medical School at Guy’s Hospital as a lecturer and pursued a PhD in electromyography. He moved to St Thomas’s and in collaboration with Alistair Bottomley and Bruce Kinnier-Wilson carried out fundamental studies on the myoelectrically controlled artificial hand, a device operated by the electrical activity of intact muscles.

Papers at the second Paris conference covered many aspects of the field, with a leaning towards electrophysiological measurements and techniques, including electroencephalography. There was the first report of an implantable pacemaker, and a number of presentations on endoradiosondes (radio pills) for intestinal measurements (figure 2). In addition to formal sessions there were scientific research exhibits and round-table discussions. Many of those present were meeting each other for the first time, discussing their specialities, discovering shared problems and forming long-term friendships. In the concluding session they formed the International Federation for Medical Electronics (IFME). At last the ‘one-man bands’ were being orchestrated.

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These initiatives reflected a growing interest in the applications of engineering to medicine. The British Institution of Radio Engineers had by now established a Medical Electronics Group, at which the inaugural lecture was given by A.V. Hill with the title ‘Biology and electronics’. And almost before the final applause at the Paris conference had faded, Zworykin was giving the Fourth Clerk Maxwell Memorial Lecture at the Institution’s Television Convention in Cambridge, choosing as his title ‘The human aspect of engineering progress’.

In this favourable climate Ronald Woolmer and Alfred Nightingale called together the colleagues who had attended the second Paris conference. They met in early autumn at the Royal College of Surgeons of England, in Lincoln’s Inn Fields, London, and established what was initially called the Interim British Section of the International Federation for Medical Electronics. The members of the interim group already belonged to one or more professional societies, institutions or associations. They elected a Steering Committee, which took the courteous step of writing to all such bodies informing them that consideration was being given to forming a specialised learned society in accordance with the objectives of the IFME. They invited comments and the overall response was highly supportive. The committee met many times in the following months to try to devise a format which would meet the members’ desire for a multidisciplinary body yet ensure that the membership was of sufficient quality to give it academic standing. Two professional organisations, one medical and one engineering, offered to take the fledgling society under their wing and represent it at the IFME. These offers were rejected by the committee on the grounds that it would bias the group in a particular direction.

The new society now needed a name. Medical Electronics Society was considered too restrictive – medicine is but a small part of biology, and electronics is but a small part of engineering – so the new society would be called the Biological Engineering Society (BES). Nightingale’s letter of invitation to the inaugural meeting is a masterful summary of the objectives:

> There are many fields on the frontiers of knowledge in the biological sciences which would profit more than they do by the application of engineering methods and engineering philosophy. Some examples are the mechanics of the human body; research on artificial organs and on aids for paralysed patients or amputees; the analysis of control mechanisms in animals and the human body in terms of servo loop theory; the design and safety of electrical equipment used in hospitals; the problems of instrumentation for high altitude flight and for hot and cold climate physiology; the automation of biochemical analysis, and the application of computers to biological problems.

The inaugural meeting was held at the Royal College of Surgeons on 10th June 1960. The Interim Committee, having fulfilled its purpose, dissolved itself. Professor R. Woolmer was voted in unanimously as President, and the first Council of the Society was elected: Dr P. Bauwens, Professor A.V. Hill, Dr A. Nightingale, Dr G. Pampiglione, Mr W.J. Perkins, Mr B. Shackel, Dr C.N. Smyth, Dr A.M. Uttley, Mr H.S. Wolff and Dr B.M. Wright. Finally a subscription of 3 guineas was agreed, and the BES became a reality.

The first scientific meeting took place at the National Institute for Medical Research, Mill Hill, on 10th June 1960. Most members knew little about other people’s work, so a format for meetings emerged: they would be held at each other’s establishments, where local members and their colleagues would provide most of the content. There would be four main scientific meetings a year, one in conjunction with the Annual General Meeting. As the majority of members were located within a 50-mile radius of London, it seemed sensible to hold two of the four meetings in the London area and two at other centres in the country. Special topic symposia would also be held, in collaboration with other organisations where appropriate. Nearly all of these meetings were arranged on Saturdays, to accommodate members who were committed to clinical duties during the week. (Throughout the 1960s most of the biomedical engineering research was carried out at institutions other than hospitals. Nevertheless much of the pioneering work of the founder members would find clinical application and the participation of the medical members was regarded as important.)

Sadly, Ronald Woolmer and Alfred Nightingale would not live to see the full fruits of their efforts. Woolmer died on 8th December 1962 at the early age of 54. Nightingale, who had been appointed first Editor of the Federation’s new journal, was tragically killed in an accident shortly afterwards on 27th February 1963; he was 40. The contribution of these men has been commemorated appropriately: Woolmer’s name is attached to an annual lecture, and that of Nightingale to an annual prize awarded for the best paper in the Federation’s journal.

Despite this setback the young society continued to thrive and to win international esteem for the UK in biomedical engineering. Researchers came from overseas to the UK to study, joined the society and remained members after their return. International links were strengthened by joint meetings with societies, which resulted in biennial ‘over the water’ meetings in The Netherlands, Northern Ireland, Denmark, Sweden, Belgium, Germany and Italy. The membership was swollen by people from those countries and from as far away as the USA, Hong Kong and Australia. The society was enjoying its heyday.
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