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Clinical audit within the UK National Health Service was introduced in 1989. Audit with reference to radiotherapy physics was an obvious application especially in the wake of major radiotherapy incidents that had occurred within the UK during the 1980s. So, 20 years after the birth of clinical audit, it seemed the time both to look back and also to show the continued relevance of audit for radiotherapy delivery.

In 1989 the definition of clinical audit was that ‘audit involves improving the quality of patient care by looking at current practice and modifying it where necessary’. Now it could be said that radiotherapy audit is concerned with demonstrating that delivered radiation doses are consistent between centres, that modern techniques are safely implemented and that every effort is made to discover systematic errors and improve overall accuracy. In the UK,

Steve Bolton [University Hospitals of Leicester NHS Trust], Chair of the RTSig Interdepartmental Audit Group, gives an update on the history and current situation with radiotherapy physics audit within the UK and describes some new exciting audits which are happening now and in the future as radiotherapy techniques advance into the 21st century.
national and regional coordination of radiotherapy audit measurements between centres is the envy of many other countries. Audit has always been traditionally associated with gaining information about financial systems, and as a result may still be interpreted by some as rather dull. However, dramatic technological developments in radiotherapy are challenging audit to keep pace and deliver its aims of maintaining safe radiotherapy delivery in the UK. A difficult challenge but an awesome motivation.

HISTORY
The first wide-reaching radiotherapy audit was developed by the International Atomic Energy Authority (IAEA) who introduced a postal dosimetry service in 1966 using TLD. The World Health Organization (WHO) joined the programme in 1968. Within the UK the initial comprehensive national dosimetry intercomparison was carried out from 1987 to 1991.1 This involved measuring standard outputs from linacs and cobalt units in a water equivalent phantom at a depth of 5 cm. A three field plan was prepared and measurements made at five points. The measurements were performed by a coordinator who went to each centre in his region. He then took the equipment to the next region, assisted with the measurements there, and handed the equipment on. Discrepancies of 5 per cent or greater were investigated by the centre concerned and, in fact, the major calibration error of a cobalt treatment unit which resulted in a patient overdose of 25 per cent was discovered by this audit.

In 1993, a method of inter-departmental audit was developed.2 This consisted of two departments visiting each other for a day and carrying out a number of tasks which would then generate a report. Four audits were completed on clinical photon and electron beams at both centres.

In 1996 a national electron audit was carried out.3 In this, one person went to each radiotherapy centre that used electrons clinically, and measured electron energy and output (for three different energies) with a single calibrated electron chamber and electrometer. A total of 156 electron beams were included in the intercomparison. The mean ratio of intercomparison measured dose to locally measured dose was 0.994 with a standard deviation of 1.8 per cent. The maximum positive deviation was 4.6 per cent and the maximum negative deviation was 5.1 per cent. One electron beam lay outside the intercomparison tolerance level of 5 per cent but subsequent follow-up confirmed agreement to within 1 per cent. So in both the national photon and electron audit, anomalies were discovered, thereby justifying the rationale in performing the audit, and also providing a benchmark for the future.

The IPEM Radiotherapy Special Interest Group concluded from all these audit results that a more organised approach to audit between different centres would be beneficial. A National Interdepartmental Audit

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### TABLE 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Chair</th>
<th>Departments</th>
<th>Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A Scottish + Northern</td>
<td>John McLellan</td>
<td>8</td>
<td>Aberdeen, Belfast, Carlisle, Dundee, Edinburgh, Glasgow, Inverness, Newcastle</td>
</tr>
<tr>
<td>Group B Trans Pennine</td>
<td>Phill Cooper</td>
<td>8</td>
<td>Hull, Leeds, Liverpool, Manchester, Middlesborough, North Wales, Preston, Sheffield</td>
</tr>
<tr>
<td>Group C Midlands</td>
<td>Alisa Ratcliffe</td>
<td>10</td>
<td>Birmingham, Coventry, Derby, Leicester, Lincoln, Northampton, Nottingham, Shrewsbury, Stoke, Wolverhampton</td>
</tr>
<tr>
<td>Group D South West</td>
<td>Robin Laney</td>
<td>11</td>
<td>Bath, Bristol, Cardiff, Cheltenham, Exeter, Plymouth, Poole, Swansea, Taunton, Torbay, Truro</td>
</tr>
<tr>
<td>Group E South East Central</td>
<td>Tony Palmer</td>
<td>12</td>
<td>Charing Cross, Cromwell, Guildford, Hammersmith, Mount Vernon, Oxford, Portsmouth, Portsmouth Spire, Reading, Royal Marsden Fulham, Royal Marsden Sutton, Southampton</td>
</tr>
<tr>
<td>Group F NE Thames</td>
<td>Jackson Zifodya</td>
<td>5</td>
<td>N. Middlesex, Oldchurch, Royal Free, St Barts, University College</td>
</tr>
<tr>
<td>Group G SE Thames</td>
<td>Nick Jenkins</td>
<td>7</td>
<td>Brighton, Canterbury, Guys &amp; St Thomas, Harley Street, Maidstone, NPL, Parkside</td>
</tr>
<tr>
<td>Group H Anglia</td>
<td>Steph Smith</td>
<td>5</td>
<td>Cambridge, Colchester, Ipswich, Norwich, Southend</td>
</tr>
<tr>
<td>National Chair</td>
<td>Steve Bolton</td>
<td></td>
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</tbody>
</table>
Network was set up which comprised eight cooperative regional groups, each with 5 to 12 members covering the 66 departments. Table 1 shows the current group configuration.

Each group arranges interdepartmental audits between each of the centres and the national audit group meets annually to coordinate audit activity across the UK.

Each group works autonomously and only reports results between the individual departments involved in each audit. The regional groups can therefore design and conduct their own audits, as well as implementing national audits. The comparisons between centres is moderated by the absolute determination of radiation dose by the National Physical Laboratory – ensuring that there is no systematic error present in all centres in a particular region.

In 2002 the South West Group described their experience of this process. They covered photons (MV and kV) and electrons and concluded that there were no dosimetric errors above 5 per cent and the introduction of quality management systems has helped to bring consistency to the audit procedure.

The Manual of Cancer Standards, published in 2004, states the required minimum standards expected. With reference to audit:

**Measure 154** – The department should have agreed to participate in a rolling programme of external quality control which involves, at minimum, a comparison of some parameters with those of another radiotherapy physics department.

**Measure 155** – The department should have carried out the comparison of at least one quality control parameter with another radiotherapy physics department and implemented any recommendations consequent on the results.

The Cancer Standards are in the process of review at the moment. In the new document (currently out for public consultation) the relevant measure states that ‘the department should have taken part in the external quality control (EQC) programme’. Audit will continue to be a means to demonstrate the ability of each department to deliver best practice.

When I became chair of the National Interdepartmental Audit Group in 2006, it was clear that some audits took a long time to carry out, reports were being delayed and in some cases audits were not being completed at all. Bearing this in mind, the National Group decided to organise a minimum national audit, which should be carried out by all departments within one year.

So in 2007, a programme of standardised minimum dosimetry audit across all centres was proposed to enable a national comparison. This would mean that at least some audit was completed, but the main intention was that most departments incorporated the minimum audit in with their own regional audit arrangements at the same time.

This national audit programme commenced with the introduction of a minimum megavoltage photon audit. The purpose of this was to set a baseline whereby all radiotherapy departments in the UK would have demonstrated that they had achieved, within a calendar year, a dosimetry standard that is clearly documented and comparable. The aim was to measure a clinically-relevant situation using both host and auditor’s equipment. The group decided that it would be essential to see the comparison between a field, planned on the local radiotherapy treatment planning system (TPS), and the actual radiation dose delivered, measured by the auditors, and corrected for daily output variation. This consisted of a single beam, planned at a specified field size and depth. A calculated dose of 2 Gy was delivered and the actual dose measured.

The audit consisted of sufficient mechanical quality assurance (QA) performed to ensure accuracy of set-up, followed by measurement of ion recombination factor, standard output, quality index (tissue phantom ratio (TPR) 20/10) as a measure of beam energy and the planned wedge field output. In addition, the use of a spreadsheet meant that the results were available instantly to exclude set-up errors, and enable further investigation of any unexpected results.

The measured values were all entered into the spreadsheet and a final report was generated with all the comparisons. Displayed in table 2 are the values of pressure and temperature, standard output, planned field comparison and quality index.

**TABLE 2.**
National MV photon audit final report.

**RESULTS**
The results are based on data received from 37 departments (56.1 per cent response). This is very disappointing and hardly reflects a national survey. Interestingly, some audit groups had a 100 per cent response whilst the others had considerably less! However, it is essential that future national audits are truly representative of all radiotherapy centres.

**OUTPUT BY DEPARTMENT**
Figure 1 shows the comparison between the host and auditor’s values for the standard output. The majority (33 out of 49 beams, 67 per cent) were at 6 MV. Most values were within 1 per cent of each other. Just one department showed a disagreement greater than 2 per cent.

**OUTPUT DIFFERENCE**
The mean of all the differences was 0.19 per cent (figure 2). The distribution follows a normal pattern with a standard deviation of 0.8 per cent.
| TABLE 2 |
|------------------|---------------|
| **Basic data**   |               |
| The host and visiting centre temperature measurement agreed within (degree C): | 0.1 |
| The host and visiting centre pressure measurement agreed within (mmHg): | 0.5 |

<table>
<thead>
<tr>
<th><strong>Photon dosimetry</strong></th>
</tr>
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<tbody>
<tr>
<td><strong>Standard output</strong></td>
</tr>
<tr>
<td>Host centre photon standard output measurement (cGy/mu) =</td>
</tr>
<tr>
<td>Visiting centre photon standard output measurement (cGy/mu) =</td>
</tr>
<tr>
<td>Percentage difference between visiting and host centre basic photon dosimetry, standard output =</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planned field (9 × 15 cm, fully wedged, 8 cm deep, isocentric, 2 Gy)</th>
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<tbody>
<tr>
<td>Percentage difference between the planned dose and the host centre measurement, corrected for daily output variation =</td>
</tr>
<tr>
<td>Percentage difference between the planned dose and the visiting centre measurement, without corrected for daily output variation =</td>
</tr>
<tr>
<td>Percentage difference between the planned dose and the visiting centre measurement, corrected for daily output variation =</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality index TPR 20/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host centre TPR 20/10 quoted value =</td>
</tr>
<tr>
<td>Visiting centre TPR 20/10 measured value =</td>
</tr>
<tr>
<td>Percentage difference between visiting and host centre TPR 20/10 values =</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th><strong>Acceptable limits</strong></th>
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<tbody>
<tr>
<td>The agreed tolerance limits for MV photon dosimetry are:</td>
</tr>
<tr>
<td>1. Host and visiting centre temperatures agree within 1 degree C and pressures within 3 mmHg.</td>
</tr>
<tr>
<td>2. Agreement between host and visiting centre standard output dosimetry within 2%.</td>
</tr>
<tr>
<td>3. Agreement between treatment planning system calculated and measured doses within 3% when corrected for daily output variations.</td>
</tr>
<tr>
<td>4. Agreement between treatment planning system calculated and measured doses within 5% without correction for daily output variations.</td>
</tr>
</tbody>
</table>
PHOTON ENERGY BY DEPARTMENT
Figure 3 shows the comparison between the host and auditor’s values for the TPR 20/10 value. Again 67 per cent of the measurements were at 6 MV. Most values were within 0.5 per cent of each other with one department varying from the auditor by greater than 1.5 per cent.

PHOTON ENERGY DIFFERENCE
The mean of all the differences was −0.17 per cent (figure 4). The distribution follows a normal pattern with a standard deviation of 0.6 per cent.

PLANNED WEDGE FIELD BY DEPARTMENT
This particular test was only carried out by 29 departments (44 per cent). The majority of values are negative, meaning that less than 2 Gy is actually delivered (figure 5). Four departments show a difference greater than 2 per cent with two of those greater than 3 per cent.

PLANNED WEDGE FIELD DIFFERENCE
The mean value overall was −0.49 per cent but the standard deviation was 1.3 per cent. The range of differences is quite broad (figure 6) showing that for the departments who contributed data, the actual dose delivered varies by up to 3 per cent. The two departments who demonstrated the largest difference in delivered dose attributed the cause to be the calculation algorithm in use, and perhaps the data, in the planning system.

CLINICAL TRIALS
It is possible that those centres which did not take part in the national audit had already been audited for clinical trials in that year. Clinical trials undertaken under the auspices of the National Cancer Research Institute (NCRI) may have radiotherapy dose audits performed by the Clinical Trials QA Group which are specific to the trial protocol. However, some trials organised by the European Organisation for Research and Treatment of Cancer (EORTC) only require some audit to have taken place – as a minimum, a dosimetry audit on machine output using thermoluminescent dosimetry (TLD). In contrast, trials involving drug companies may involve extensive audit via the European Society for Therapeutic Radiology and Oncology (ESTRO) EQUAL QA team. The variability in the nature and quantity of audit required by clinical trial protocols, particularly those from outside the UK, makes it difficult for the Interdepartmental Audit Group to give formal guidance but it is recommended that audits for clinical trials should be considered as supplementary to interdepartmental audit and certainly not a replacement.

ELECTRONS
Since the national audit in 1996 there have been two electron Codes of Practice issued. The Interdepartmental Audit Group have decided to introduce a national minimum electron audit to be performed between summer 2009 and summer 2010. This is a national audit to be delivered via the regional audit groups. A spreadsheet has been devised to enable all the measurements to be tabulated and a results page produced. This will then give a picture of the state of the nation with regard to electron dosimetry, to compare with the results published in 1997. The parameters are to be measured for three different beams and include the beam energy, the output and the measured dose for a planned single field treatment using a
rectangle measuring 7 × 4 cm. The results from this national audit will be presented at the next IPEM Biennial Radiotherapy meeting in 2010.

**NATIONAL PHYSICAL LABORATORY (NPL)**
The NPL was invited by IPEM to start conducting reference dosimetry audits in 1995. This work was in addition to interdepartmental audit and enabled a direct link to the national dosimetry standard. In the intervening 14 years they have conducted 40 MV photon audits, six electron audits (under the 1996 Code of Practice), ten electron audits (under the 2003 Code) and nine kV photon audits.

It is interesting to compare the photon audit results with those measured by NPL over this time (table 3).

The mean and standard deviation for quality index are the same, showing that ratios are reproducible. The standard deviation for the output measurements varied for the NPL from 1.5 per cent to 0.7 per cent with 0.8 per cent for the minimum audit. The conclusion we can draw is that the basic dosimetry (output and quality index) in the UK has improved in accuracy over the last 15 years. National photon audits have demonstrated that the likelihood of basic dosimetry calibration errors is small, so as radiotherapy techniques become more complex, the audit methods can adapt to reflect this trend, with knowledge that the fundamental calibration is valid.

**DOSE DELIVERY IN THE PATIENT**
Radiotherapy is a lot more than output and beam energy. The 3D (and perhaps 4D) distribution and accuracy of delivered dose to the patient is the critical parameter that will dictate if we comply with the accepted clinical standards laid down in publications from the International Commission on Radiation Units and Measurements (ICRU). A new ICRU report will be published early in 2010 which will consider new treatment modalities including Intensity Modulated Radiotherapy (IMRT).

This will mean that the previous ICRU 5 per cent point-dose accuracy specification will be replaced by a volumetric dose accuracy specification. The proposed new ICRU volumetric dose accuracy specification is that in a high dose gradient, 85 per cent of dose points lie within 5 mm, and in a low dose gradient, 85 per cent of points lie within 5 per cent of predicted dose, normalized to the prescribed dose. The recommendations will also state that there should be appropriate QA of treatment planning systems and that patient QA is not limited to single point dose check. In addition, phantom QA should use measured dose and not be limited to a single measurement point.

Departments should use independent dose calculation algorithms with similar or better dose calculation accuracy than the main planning system.

However, this volumetric dose accuracy specification is not a suitable tolerance for IMRT verification. According to the recently published IPEM Report ‘Guidance for the Clinical Implementation of IMRT’, an example clinical tolerance for a combined dose distribution to treat the prostate would be for 98 per cent of dose points to lie within 3 per cent or 3 mm of the predicted dose.

**IMRT**
The uptake of IMRT has been slow in the UK, despite national recommendations and expectations that it should be clinically implemented. Because of the increased complexity of the technique compared to conventional

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**TABLE 3**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>QI mean</td>
<td>0.998</td>
<td>0.998</td>
</tr>
<tr>
<td>QI standard deviation</td>
<td>0.6%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Output mean</td>
<td>1.002</td>
<td>1.003</td>
</tr>
<tr>
<td>Output standard deviation</td>
<td>0.8%</td>
<td>1.5% (1992)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7% (2009)</td>
</tr>
</tbody>
</table>
radiotherapy, it would seem appropriate to develop an audit method in order to increase confidence in centres starting IMRT programs. It is also a reassurance that this powerful but complex technique has been implemented safely across the UK.

The ESTRO guidelines on IMRT verification\textsuperscript{11} state that ‘more information is urgently needed about the accuracy of IMRT treatment delivery in Europe’. Within the United States, the use of IMRT is far more prevalent than in the UK, and in 2006 the results of a study of tests performed by the Radiological Physics Centre (RPC), of a special head-and-neck phantom mailed to 128 North American institutions wishing to participate in a Radiation Therapy Oncology Group (RTOG) trial, showed unexpected large deviations between planned and measured IMRT dose distributions.\textsuperscript{12,13} Roughly a third (48/163) of all the irradiations of the head-and-neck phantom failed to meet the criteria: the ratio of the measured dose (as determined from TLDs) to institutions’ stated dose was expected to agree within 7 per cent, and the distance-to-agreement in the high-dose gradient region near the organs at risk (OAR) was expected to be no greater than 4 mm. Discrepancies in the dose delivery were attributed to a variety of reasons including the use of inappropriate data in the treatment planning systems and collimator positioning errors.

It has been realised that only a small number of radiotherapy departments in the UK are using IMRT regularly even though all departments have had the equipment capability for some time. Difficulty accessing external validation can be a significant barrier for centres wishing to progress towards IMRT. There is an understandable concern from radiotherapy physicists that the quality of local implementation of IMRT techniques is adequately assessed before patient treatments commence. The results of the RTOG audit are no doubt a major contributing factor to this perspective. As a consequence, the National Radiotherapy Implementation Group (NRIG), who wish to encourage the wider take-up of routine IMRT within the UK, has set up a working party to develop an IMRT audit. The method devised means that all UK radiotherapy departments can set up an IMRT plan of their own choosing on their treatment planning system (TPS) and then irradiate dosimetry film in a standard water-equivalent phantom at a standard depth. In addition, a set of alanine dosemeters will be used to measure absolute delivered dose at a defined point. Any commercial TPS can be used as long as the calculated dose grid can be exported in a standard format.

Figures 7 and 8 show two dose distributions with isodose colourwash – one from a film irradiated at a known depth in a phantom and one from the TPS. In figure 9 the two sets of isodoses are superimposed. The distributions have been deliberately chosen so that the match is relatively poor.

Depending on the dose accuracy specification chosen (commonly called the gamma analysis) the number of pixels that pass or fail the specification will vary (figures 10, 11 and 12). In the display, the pixels coloured red fail, whereas the ones coloured green pass. So for a dose accuracy specification of 3 mm and 3 per cent, 31.8 per cent fail, but if the specification is set to 4 mm and 4 per cent, then only 18.1 per cent fail. At a specification of 5 mm and 5 per cent the fail rate is down to 7.3 per cent (92.7 per cent pass). Although this IMRT plan would pass the new ICRU recommendations (but not the tolerances set down in
the IPEM report), it is clear that care must be taken in deciding the appropriate dose accuracy specification.

The expectation is that the proposed national IMRT audit will be an independent check on the efficient implementation on IMRT in the UK and identify problems in modelling and delivery. It will also act as a pre-clinical independent check for centres starting IMRT or moving to new treatment sites and provide a snapshot of the range and complexity of IMRT being practiced in the UK. Ultimately it will satisfy the need for independent IMRT audit methods that are being proposed in national guidelines and generate published data presenting the results of the audit to the radiotherapy community. However, the use of QA audits for centres participating in trials involving IMRT will be a useful supplement to the basic audit proposed by the national audit group.

**IMAGING**

Imaging in radiotherapy plays a major part of the planning and treatment process. CT and MR scans have been used for target delineation for many years and the introduction of PET imaging has meant that image registration is now a relatively common occurrence in many departments. Now, of course, the availability of cone beam CT (CBCT) and pre-treatment kV imaging whilst on the treatment machine couch, as well as portal imaging (EPID), has meant that a patient is imaged many times both before and during treatment. All these images are used for treatment planning, to assist with the patient set-up. Any errors at this stage will contribute to over- or under-dose to the patient, or even geometric miss of the target.

The Interdepartmental Audit Group has discussed the possibility of a national imaging audit and the South East Central group are in the process of developing this over the next 12 months. The aims will be to investigate current practices in pre-treatment and verification imaging, with particular emphasis on patient concomitant dose and image quality. If consistent, quantitative and robust techniques for assessing imaging dose and image quality can be adopted, then these will be compatible with current practice in diagnostic radiology and will allow meaningful comparisons to be made between similar modalities. Ultimately, baseline dose and image quality performance standards can be established, so aiding a future drive towards optimisation.

The scope of the audit will include pre-treatment CT, set-up and treatment verification. Possible future developments would consider digitally reconstructed radiographs (DRR), EPID dosimetry and image fusion. As with all audit, the hope is that this will yield results which are clinically representative and practically useful, yet be a sufficiently small-scale project to be achievable in a realistic time frame!

**CONCLUSION**

It is clear that audit has a major part to play in establishing confidence in the whole radiotherapy process. It is accepted that part of the commissioning of a new treatment machine includes external audit, not because we feel that something may be wrong but to demonstrate that everything is right and within accepted tolerances.

At the Royal Adelaide Hospital in Australia, it was discovered that one of four linear accelerators delivered a dose up to 5 per cent lower than recommended during a 2-year period from July 2004 to 2006. This error was
A regular, independent, tertiary dosimetric survey for the linear accelerators would have detected this error earlier if this system were in place. This would not prevent error, but if done frequently (perhaps yearly) and when there are changes to equipment or treatment technique, would reduce the period in which the error goes undetected and thus reduce the number of patients that would be affected by a fundamental dose error.

Options to advance the development for establishing an independent calibration service would be to arrange such a service with a third party or to lobby, along with other groups, for the funding of a national programme.

The document ‘Towards Safer Radiotherapy’ recommends that ‘all centres should participate in dosimetric audit networks’. Also, ‘comparative audits between departments can provide valuable opportunities to ensure safe delivery of radiotherapy and consistency of patient outcomes’.

Within radiotherapy in the UK, we are very fortunate to have an established audit network, which if utilised properly and fully would allow all of us to not only demonstrate compliance with national standards but also provide assurance that our patients are receiving the prescribed dose accurately. The audit network will ensure accurate basic radiation dosimetry and also be the means of motivation to modernise techniques and enable support from peers in so doing. Research and development, modernisation and application of state-of-the-art techniques from all specialities in medical physics for the benefit of radiotherapy patients are key goals; this must however be accompanied by robust audit methodologies.

Participating in and developing new forms of audit which reflect the modern methods used in 21st-century radiotherapy should be a major goal for those of us who are privileged to work in radiotherapy physics.

ACKNOWLEDGEMENTS AND THANKS
Acknowledgments and thanks to all those who contributed to this article, especially Laura Gandon, Tony Palmer and Geoff Budgell for supplying the photos and providing helpful and insightful comments!
n recent years, the study of the heart’s electrical activity (called cardiac electrophysiology) has evolved from a discipline of interest primarily to physicians and physiologists to one that has caught the attention of physicists, mathematicians and engineers. Such scientists have come to realize that cardiac dynamics are characterised by many of the same principles that underlie the physical systems with which they are intimately familiar. In this context, mathematical modelling has proved to be the perfect framework to combine the quantitative data coming from research and experiments with the qualitative understanding in order to produce an explanatory and predictive tool.

**CARDIAC TISSUE AS A MODEL OF EXCITABLE MEDIA**

Excitable media are spatially distributed systems which have the ability to propagate signals without damping. This is in contrast to passive wave propagation, which is characterised by a gradual damping of signal amplitude due to friction. Although it could be challenging to find an exact definition, excitable media can be defined in general as systems composed of elementary segments or cells, each of which possesses the following properties: (i) a well-defined rest state; (ii) a threshold for excitation; (iii) a refractory period in which the system cannot be re-excited; and (iv) a diffusive-type coupling to its neighbours. Examples of excitable media may include signal transmission in nerves or cortical tissue, or propagation of electrical activity in cardiac tissue. By a threshold of excitation, we mean that any external stimulus applied to a cell that keeps the cell below this threshold produces a qualitatively different result than a stimulus that raises the cell above the threshold. Stimuli below the threshold are damped out and produce no persistent change in the system, which simply returns to the rest state. However, stimuli above the threshold induce the cell to change from its rest state to an excited state (see figure 1).

This change produces a pulse in time whose shape and nature are determined by the nonlinear properties of the medium and do not depend on the form of the external excitation. In spatially-extended excitable systems, the excitation pulse may be carried over from one elementary segment to the next by means of a diffusive coupling. As each element undergoes an excursion from resting state, it causes its neighbours to move over the excitation threshold and fire their active response. The excitability of the system and the coupling strength between neighbours determines the minimum size of tissue required for a pulse to expand and propagate as a travelling wave front.

All of these properties can be found and characterised in the study of cardiac muscle. In consequence, the following section provides a detailed description on how cardiac cells and tissue qualify as excitable media.

**THE CARDIAC ACTION POTENTIAL**

Cardiac muscle cells or myocytes are approximately flattened tubes, about 80–100 μm long in human ventricular tissue, with elliptic cross sections with a major axis of 10–20 μm. They are arranged in discrete layers of fibres called sheets, roughly parallel to the heart surfaces (epicardium and endocardium), with the fiber axis continuously rotating counter-clockwise from epicardium to endocardium in a range of 100º–120º as viewed from the top of epicardium. Each cardiac muscle cell is bounded by a thin (5–7 nm) phospholipic membrane or sarcolemma. This membrane encapsulates a small volume that is known as the intracellular space, whereas the extracellular or interstitial space is therefore defined as the space that lies outside the sarcolemma. The membrane is heterogeneous, with numerous large, complex proteins embedded within it, that combine to form small pores in the cell membrane. Under most circumstances these pores are selectively permeable, allowing the pass of only specific ions through the membrane and only under certain conditions, the reason why they are commonly called ion channels.
The main ions that are of interest in cardiac electrophysiology are Na+, K+, Ca2+ and Cl−. At rest, the intracellular and extracellular concentrations of each ion are substantially different. In principle, this difference in concentrations would produce a chemical force that would cause ions to flow down their concentration gradient to create a uniform distribution at both sides of the membrane.

Nevertheless, different ionic concentrations also implies a net electrical charge difference between both sides of the membrane, causing the establishment of an electrical gradient that acts to oppose the chemical gradient, thus allowing intra- and extra-cellular concentrations to be different. Consequently, at rest the cell membrane maintains a net membrane potential, which for cardiac muscle cells generally is between −90 and −80 mV, and the cell membrane is said to be in a polarised state.

During electrical excitation, the cell’s electrochemical equilibrium is broken, allowing ions to flow through ion channels to which they are permeable, if opened. Any positive increase of the transmembrane potential towards zero is therefore known as depolarisation, while the term repolarisation refers to the returning of the cell to its negative resting state. Small perturbations in the potential difference across the cell membrane produce only a passive, linear response of the cardiac cell, followed by the returning of the transmembrane potential towards its resting state. On the contrary, if a sufficiently large stimulus able to increase the transmembrane potential above the threshold potential is applied, an active, non-linear response, known as the action potential, will be elicited (figure 2).

The sharp upstroke (phase 0) at the start of the action potential after the supra-threshold stimulus is due to a rapid influx of sodium ions, creating the sodium current INa. Throughout the whole action potential duration there are potassium-based currents IK that tend to bring the transmembrane potential back to the resting potential, as is for instance the case of the rapid outward potassium current acting during phase 1. However, in phase 2 the influx of calcium ions in the form of slower inward currents ICa is able to compensate potassium currents, creating a relatively flat plateau in the action potential. In phase 3 the calcium currents cease to hold the membrane potential in a depolarised state and the potassium currents return the cell to the resting state, also known as phase 4.

As can be also observed in figure 2, one of the main characteristics of cardiac cells is the beat-to-beat variability in action potential properties, as is for instance the case of the action potential duration (APD). The inter-beat variation of these properties is related to the time needed by the ion channels of the cell membrane to fully recover their resting properties prior to the next excitation. If the diastolic interval (DI), also known as recovery time and defined as the time between the end of repolarisation and the start of the next depolarisation of the membrane (see figure 2), is sufficiently long for the membrane to have fully recovered, it will be followed by a long APD that is independent of the DI. In contrast, a short DI that only allows partial recovery will be followed by a short APD. This dependence of the APD on the DI can be represented in the form of the APD restitution curve, which relates the APD at a given point in the tissue with the previous diastolic interval DI at the same point. Since determining the end of the repolarisation is often hard, APDs and DIs are usually measured at a given potential threshold (typically between 80 per cent and 95 per cent of repolarisation of the transmembrane potential).
**SCOPE | FEATURE**

**BIOPHYSICALLY-BASED CARDIAC IONIC MODELS**

The Luo Rudy I model was studied, and compiled with different software (CellML and Matlab) in order to see the differences that may occur between results.

The model introduced in 1991 by Luo and Rudy, and its consecutive actualisations, probably constitutes the most extensively-used model in the field of computational cardiac electrophysiology. The model, built on the Beeler–Reuter model, adjusts parameters and includes additional currents in order to reproduce recent experimental results more accurately, especially on potassium ion dynamics. A total of six individual currents describe the cellular processes:

\[
I_{\text{ion}} = I_{\text{Na}} + I_{\text{Ca}} + I_{\text{K}} + I_{\text{K1}} + I_{\text{Kp}} + I_{\text{p}}
\]

where \(I_{\text{Na}}\) newly accounts for the fast inward sodium current responsible for the action potential depolarisation, \(I_{\text{Ca}}\) is a slow inward-calcium related current defined as in the Beeler–Reuter model, whereas \(I_{\text{K}}, I_{\text{K1}}, I_{\text{Kp}}\), and \(I_{\text{p}}\) respectively represent time-dependent, time-independent, plateau and background potassium currents. Newman boundary conditions were used, and both intracellular and extracellular parameters of the cell were taken into account when developing the model. The action potential for the ventricular cells and the current components obtained after the simulation in Matlab are presented in the figure 3.

After compiling the model in CellML, the results obtained were similar, see figure 4.

**CONCLUSIONS**

The Matlab model was conceived in such a way that allows the modification of several parameters, in order to observe an altered action potential. Although many models were developed in literature, this particular one is user friendly; the modifications of the parameters can be made very easy. Both results are in concordance with the results obtained in the literature. These models are able to reproduce accurately experimentally-measured cellular currents and action potential shapes.

**REFERENCES**

Digital Seating Services

L. Tasker (ABM University NHS Trust, Swansea) and P. Watson (Musgrave Hospital, Belfast) explain a new digital method of designing wheelchair seating systems

The development of Digital Seating Services (DSS) enables the Rehabilitation Engineering Centres in Belfast and Swansea to speed up the assessment and manufacture of the highly specialist wheelchair seating systems they provide to clients with complex postural requirements.

Creating Custom-Made Seating Systems

Special seating systems exist in many forms; a proportion of these (about one-third) are custom-made shapes, which are taken directly from the client to accommodate or correct anatomical or physical problems, for example skeletal deformities or range of motion problems in the lower extremities. Various techniques are employed to capture and manufacture these shapes; the most popular method is vacuum consolidation using bead bags. These hand-sculpted techniques are heavily reliant on highly-skilled professionals, where the shape of the client is often retained within a plaster cast. The most commonly-used technique at Swansea was foam in place, which used liquid viscoelastic foam to form the desired shape from the plaster cast. This technique can be labour intensive and outcomes can be unpredictable. In addition, the materials are costly (at approximately £500 for a large mould). In Belfast, previous methods included hand-carved foam, resin bead bag, foam in place, matrix and moulded seat inserts, all of which required the typical hand-sculpted techniques.

Dr Peter Watson has developed a method which uses a Microscribe, where a pointer is used to digitise the surface of a deformable bead bag, as shown in figure 1. These CAD (computer-aided design) files are processed by inserting the shape into templates of foam block shapes (figure 2). CAM (computer-aided manufacture) software generates the specified milling toolpaths for the defined shapes. A three-axis CNC machine is used to carve the shapes from foam blocks where, due to limitations of the cutter’s depth, more than one foam block is used to gain the required height. Belfast has manufactured approximately 250 complete seating systems, comprising of a separate seat and backrest.

Ad to be placed in this space
cushion using this digital method, an example is shown in figure 3.

**LASER SCANNING**

The DSS team at Swansea have adopted and adapted these processes, by using a Microscan which is a desktop laser scanner, offering six degrees-of-freedom, non-contact laser scanning (figure 4). The laser scans the shape of the bead bag, where the shape has been captured from the client. The CAD files are processed (figure 5) and prepared by splitting the shape into layers for milling using similar CAM software (figure 6) which is exported to the CNC foam carver (figure 7). Experimentation by the DSS at Swansea has been ongoing since April 2007 and the first cushion manufacturing began in April 2008, since when 19 patients have benefited from the new process.

The technologies employed are designed for graphical arts, animation and industrial design, production and inspection; therefore the DSS teams have transferred the applications of these technologies into this specialist field to achieve a novel manufacturing process of postural supports.

**TECHNOLOGICAL BENEFITS**

The digital process has meant reductions in fabrication and clinical time, therefore providing a more efficient turn-around time for the client, where the aim is to provide an assessment and trial fitting in one day. The new method has resulted in significant reductions in material costs (approximately 60 per cent) when compared to previous techniques. Belfast has shown that a saving of £2,000 per seat is easily achievable when compared to commercial suppliers, which is particularly significant for children’s services where growth changes are more frequently needed.

The use of these technologies provides a more scientific approach to the process, where several research and development ventures are planned and ongoing. For example, projects include the modification of the machine to achieve deeper cuts which will result in faster times. Ongoing research includes using the equipment/software to scientifically analyse the shapes of the customised systems. The resultant digital files are retained for future manufacturing (previously plaster casts were discarded). This can reduce expensive re-productions to replace/modify systems (predicted 30 per cent of systems). The CAD software also allows the shapes to be manipulated digitally to enhance or reduce features of the seat or they can be tilted/rotated within the foam blocks to enhance the postural effects for the client. Different foams can be specified to be used in different sections of the seat, depending on the desired effect, for example softer foam for pressure relief for the buttocks and stiffer foam for upper-body support.

Collaborative work between Belfast and Swansea has allowed the sharing of information regarding equipment and material sources. Software training was provided using a video link between the centres. Since these two services share a common process they can benefit from one another’s research and cost-reduction measures. If more centres adopt this then the potential benefits will be multiplied, allowing multicentre research to develop across the NHS.

**WINNING AWARDS**

This joint project between the Rehabilitation Engineering Centres at Belfast and Swansea has received national recognition at the Allied Health Professionals and Healthcare Scientists Awards on 27th February 2009. Dr Peter Watson and Lorna Tasker received the award for the category ‘Innovation in Patient or Clinical Services: Healthcare Science’ for their development of Digital Seating Services (DSS).

**ACKNOWLEDGEMENTS**

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The DSS in Belfast, led by Dr Peter Watson (Principal Bioengineer), are:
- Sharon Bailie (Pre-registration Clinical Scientist)
- Keith Shields (Rehabilitation Engineer)

The Swansea team are:
- Nigel Shapcott (Consultant Clinical Scientist)
- Anthony Beddow (Workshop Manager)
- Lorna Tasker (Pre-registration Clinical Scientist)
- Dean Williams (Medical Technical Officer)
- James Nasrat (Trainee Clinical Scientist)
- David Holmes (Medical Technical Officer)
THE PHYSICS AND TECHNOLOGY OF MEDICAL ULTRASOUND
MARK BREWIN Royal London Hospital, Scientific Organiser
MICHAEL LYNN Royal Berkshire Hospital, UNIRSIG Chairman
BAR CONVENT, YORK 3rd–4th March 2009

THIS MEETING OR A version of this conference has been running in one format or another for decades. The idea was hatched in the 1970s in order to both disseminate and share research and findings in the fledgling that was medical ultrasound. Indeed, in this time of cutbacks and financial mishaps, the attendance was as high as any delegate could remember.

After a brief sojourn in 2007 to Birmingham, the troop now returned to grand old York. The Monday night saw pie and pint appreciation at the Brigantes bar on Micklegate. The setting for the meeting itself was the oldest living convent in England. Over the two days, the audience was presented with a wealth of knowledge. One session on safety saw five speakers with around 130 years of experience in the field. The programme was full, to say the least, with a total of 33 talks. Four invited speakers came from a wide range of backgrounds.

Carmel Moran (University of Edinburgh) started proceedings by presenting work on high frequency/resolution imaging under the premise of pre-clinical ultrasound. She provided themes which were taken up throughout the two day-meeting. Small animals (and even smaller fish) are popular in research work but present challenges in the selection of ultrasound equipment capable of imaging them (figure 1). A number of images of marmoset ovaries showing details of follicles were shown and a comparison between scanners (Diasus, VisualSonics, Sonosite and Philips) was examined. The resolution capability, by way of the Resolution Index from the ‘Edinburgh Pipe phantom’, of the scanners and their associated high frequency probes, in the range 25–55 MHz, was also investigated.

QUALITY ASSURANCE
The mainstay, or fuel for the fire of debate, at any self-respecting ultrasound physics meeting is quality assurance. Three of the seven sessions were given over to this end. The keynote speech on QA was given by Nick Dudley (United Lincolnshire Hospitals and UNIRSIG working group, Grantham). He outlined the revised IPEM guidelines for QA that are due to be released as an IPEM Report later this year. This will be a revision of Reports 70 and 71. The areas of testing involved B-mode, Doppler and safety. Some tests have been shown to be simplified such as sensitivity which can be measured by inspection of the axial banding (see figure 2). His fourth slide

![Figure 1](image_url)
A high frequency, 50 MHz, image of a zebra fish using a VisualSonics scanner.
grabbed our attention by stating that ‘there is no evidence base for currently recommended QA’. Perhaps most of the audience already knew this judging by the interest paid to presentations on the ‘novel’ phantoms, test methods and software that were discussed during this meeting. Both the Sonora ‘First Call’ system and the Nickel device were evaluated while a number of papers looked into the research end of test objects. The merits of ‘Edinburgh Pipes’, ‘Austrian Voids’ and an automatic assessment of spherical targets were thoroughly and fairly reviewed by several speakers. In this way, we learned a great deal about B-mode image quality. However, Nick pointed out that ‘very few centres do Doppler QA and output measurement’. This may not be the case but several speakers had these omissions firmly in mind.

COMPARING QUALITATIVE WITH QUANTITATIVE

The theme of comparing qualitative with quantitative was taken up by several speakers. Sally Moore (Leeds General Infirmary) gave an entertaining account of trying to compare user evaluation of breast ultrasound scanner performance versus the ability of different test objects to discriminate between good/poor scanners. Andrew Fairhead (University of Aberdeen) reported on an alternative way of quantifying breast tissue density for the purposes of breast screening using differences in the speed of sound in fatty and glandular tissues. Mike Halliwell (Bristol General Hospital) invited the audience to further consider these differences. In his talk, he presented the challenges that body fat presents to ultrasound imaging. He noted the effects of compression on its appearance and behaviour whilst trying to quantify these with in vitro and in vivo measurements. Deirdre King (through Jacinta Browne, Dublin Institute of Technology) reminded us that fat layers are a common limiting factor in renal imaging but was unable to quantify the effects of a fat mimicking layer on Doppler waveforms using a ‘string’ phantom. She hopes to investigate this further with a ‘flow’ phantom.

The other two invited speakers were Professors Tony McHale (University of Ulster, Northern Ireland) and David Evans (University of Leicester). The former delivered an enlightening insight into the wackier world of ultrasound use. In his 30-minute presentation he described three approaches which they have employed to exploit ultrasound to achieve site-specific therapeutic effects for the treatment of solid tumours. These were CEFUS therapy, ultrasound mediated chemotherapy and ultrasound mediated gene transfer. This provided an intriguing look into little-known uses of ultrasound. David Evans gave us a broadband revision of recent developments in Doppler ultrasound. He gave an indication of where Doppler techniques can be improved regarding the measurement of velocity, improvement of frame rate and improvement of axial resolution, particularly via the incorporation of galloping leaps in electronics and information technologies.

OUTPUT MEASUREMENTS

It was noted that enthusiastic applause was given to presentations concerning output measurement and there were some novel approaches here, too. Barry Ward (Freemantle Hospital, Newcastle upon Tyne) had made a Google search of ‘keepsake’ images to analyse the displayed value of Thermal and Mechanical Index on still images. It became evident that the operators were flouting the recommended values of TI and, in particular, MI. Indeed the displayed values of MI (see figure 3)

![Figure 2.](image)

**Figure 2.** Axial banding or reverberation is used as a QA functional check for uniformity.
**FIGURE 3.** Graph of displayed MIs on keepsake fetal ultrasound scans from Ward’s survey.

**FIGURE 4.** An anatomically relevant phantom of a baby skull to be used in a NPL survey of the temperature increase caused by neonatal clinical ultrasound.
DESIGN OF TREATMENT ROOM FACILITIES
COURT DEVELOPMENTS IN THE
Royal Infirmary) brought us back to the subject of the first
where the model will be used.
now looking for hospitals to participate in the survey,
made from MRI data supplied to a 3D printer and NPL is
clinical practice in neonatal ultrasound. This skull was
be used in the Department of Health funded survey on
obtain the anatomical skull model (see figure 4) that will
Teddington) was equally up-to-date with the method used
Gianluca Memoli
should not exceed 0.3 for non-diagnostic scans and BMUS
guidelines state a theoretical risk at greater than 0.7.
Kevin Martin (Leicester
Roal Infirmary)
JAMES ROBERTS
ARNOLD RUST
Radiation Protection Dept, Velindre Hospital, Cardiff
18th March 2009
PERMANENT STRUCTURES INCLUDING
SPECIFICATION AND DATA
After an initial welcome, Philip Mayles (Clatterbridge
Centre for Oncology, Wirral) presented the issues
associated with the design and modification of a
permanent radiotherapy treatment facility. The
importance of designing to acceptable time-averaged
dose rates (TADR, TADR2000) rather than the
instantaneous dose rate (IDR) limit was emphasised. In
order to optimise shielding thicknesses, it was advised
that departmental record and verify systems be utilised
to assess exactly the dose delivered at each gantry angle
for the room in question taking into account the
potential for introduction of new techniques.
Common challenges associated with modification of
existing bunkers were presented using real-life
eamples. The addition of steel to a primary barrier was
shown as an effective way to remedy surprisingly high
dose rates measured in a maze. The issue arose due to an
inaccurate plan drawing of the facility on which earlier
calculations had been based. Finally, the benefit of
adding nibs and baffles to existing structures was
discussed through example. The retro-fitting of a
concrete nib at the far end of an existing facility was
proven to reduce dose rates at the maze entrance by a
factor of three. This nib has since become a feature of
new designs at the department’s satellite centre.
USE OF MONTE CARLO TECHNIQUES IN THE
DESIGN OF TREATMENT ROOMS
Following a number of presentations describing the
empirical approach to bunker design, Stuart Green
(Birmingham Cancer Centre) highlighted the advantages
associated with the use of Monte Carlo methods. The
presentation concentrated mainly on the MCNP Monte
Carlo code available free (until the end of 2009!) from the
Los Alamos/NEA Data-Bank but also introduced the
range of others available and their relative merits, e.g.
McBend, EGS, FLUKA and GEANT.
The differences between results derived from MCNP
and accepted ‘rules of thumb’ were explored which
demonstrated that large errors could be present when
relying upon simple methodology. In particular, the
energy of scattered radiation appeared to be rather less
than that usually recommended leading, for example,
to the potential for over-specified lead doors.
The immense benefits of the visual editor (vised)
available as standard with the latest MCNP versions
were demonstrated using on-screen examples. It was
shown how easily particles could be visually tracked
during a simulation to highlight specific weak points in
the shielding of a treatment bunker. In addition, the use
of mesh tallies over the surface of a bunker geometry
could be used to produce a colour-coded contour map
of the doses in and around a bunker. Figure 1 illustrates
a high dose-rate region at a maze entrance resulting
from scattered radiation. Dr Green also explained how
a simulation taking approximately two days in 1995
could be performed in close to 12 minutes today using
only a fraction of a machine cluster.
In addition to the transport of photons, the use of
MCNP to simulate neutron transport was presented.
The results obtained from simulation of a 15 MV Elekta
accelerator were displayed and compared with
measurement results for a range of gantry angles and
field sizes. From this the importance of the flattening
filter material on neutron production was emphasised.
NEUTRON CONTAMINATION OF 10 MV X-RAYS
A long-standing and widely-accepted rule of thumb in
radiotherapy room design for linear accelerators is that
photoneutron production is significant only above 10
MV photon operation and insignificant for all energies
of electron operation. The presentation by Peter Rudd
(Guy’s and St Thomas’ NHS Foundation Trust,
London), based upon an earlier BJR publication, served
to disabuse us of this rather comfortable notion and
reminded RPAs of the need to consider neutron
production in their design calculations.
In practice, the maze length and photon scatter
pathway are deliberately designed to render a radiation
shielding door unnecessary. In this case, an acceptable
‘photon’ maze design usually leads to satisfactory
neutron attenuation, provided that no obvious neutron

CURRENT DEVELOPMENTS IN THE
DESIGN OF TREATMENT ROOM FACILITIES
JAMES ROBERTS, ARNOLD RUST
Radiation Protection Dept, Velindre Hospital, Cardiff
SOCIEITY OF CHEMICAL INDUSTRY, LONDON 18th March 2009

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design flaws are included. However, space and other constraints are increasingly leading to the use of high-density shielding materials, resulting in designs with either a shortened maze, or no maze at all, thus denying the designer this advantage.

Dr Rudd presented results confirming neutron production around the heads of Varian and Elekta linear accelerators, even in electron mode. Although neutron effective dose rate is a tiny fraction of that due to photons for a clinical 10 MV beam, the lack of neutron attenuation by distance afforded by a maze necessitated additional neutron protection in a room design with a 'direct access' door. Protection consisted of a polyethylene lining to the heavily-leaded door, part of which was boron loaded. In the case of short mazes, less than 7 metres long, neutron dose rate could still be significant at the entrance, leading to the need for neutron remediation measures. Radiation Protection Advisors beware!

I M AS I AM CURRENTLY RESEARCHING for my PhD in medical ultrasound, I was delighted to be accepted for a poster presentation at the American Institute of Ultrasound in Medicine (AIUM) Annual Convention in New York. To take advantage of my being in the United States I made arrangements for a short scientific visit to the Medical Physics Department at the University of Wisconsin-Madison. I was fortunate enough to obtain a bursary award from IPEM to partially fund my travel expenses; this report outlines my experience of both the convention and the scientific visit.

The AIUM convention was held over a 4-day period in the Marriott Marquis in Times Square, New York. This year’s convention was a huge success with almost 2,000 delegates in attendance. The preconvention programme was held on 2nd April; the programme consisted of full-day and half-day courses. Topics covered in these courses included Doppler ultrasound in obstetrics, critical care ultrasound and screening for ovarian cancer. The topic I found most interesting was ‘Ultrasound Present and Future: Emerging Markets and New Technologies’, where technologies such as matrix transducers, compound imaging, elastography, volume imaging and picture archiving were discussed. Furthermore, new emerging ultrasound technologies were outlined. These included 3- and 4-dimensional imaging and handheld imaging systems.

That evening I was invited to attend the AIUM Presidential Reception, which was held in the presidential suite on the 47th floor of the Marriott Marquis (figure 1). The reception was well attended and we were treated to wine and canapés. During the evening I had the opportunity to meet other new members and AIUM leadership from around the world.

The next three days consisted of an intense programme of educational courses, workshops and scientific sessions. At any one time there were six parallel sessions spread across four floors of hotel. The scientific sessions were divided into 12 topics and I chose to attend the basic science, breast ultrasound and clinical tissue characterisation sessions.

On the first morning we were entertained by the world’s best-known collegiate a capella group, the Yale Whiffenpoofs. Shortly afterwards we were treated to a Grand Opening Luncheon in the exhibit hall. With over 200 commercial vendors from around the world exhibiting we had the opportunity to view the latest developments in ultrasonic imaging.

Following the luncheon the first categorical courses began; I attended the Quantitative Ultrasound Breast Imaging course. This course presented a synopsis of ultrasound-based parametric imaging techniques for quantitative imaging of breast tissue. The first speaker was William D. O’Brien (University of Illinois, Urbana, IL, USA), who described an imaging approach that uses a fit between theoretical backscatter models and experimental backscatter data. The talk which I found most interesting in this session was by Kevin D. Donohue (University of Kentucky, Lexington, KY, USA) who presented his innovative approach for automatically detecting and characterising small-scale structures from RF ultrasound B-scans using the generalised spectrum (figure 2). Professor Donohue used the generalised spectrum to classify regions based on their scattering properties. Using these data he identified suspicious regions based on their occurrence relative to large-scale tissue structures. Quantitative characterisations of these regions were then used to create parametric images for...
FIGURE 1. Meeting new members at the Presidential Reception.

FIGURE 2. Examples of RF segments and GS in tissue.
Phantom Development

1. Data acquisition
   64 slice CT scan (Siemens Sensation Cardiac 64) from healthy volunteer

2. Generation of computer model
   Generic model of the renal artery lumen was generated in Solid Works

3. Rapid Prototyping (RP)
   Computer model input into the rapid prototyping machine (Zprint 3D printer) - physical model of the renal artery constructed

4. Soft tool
   Silicone soft tool clamped together and low melting alloy MCP 47 (melting point 47°C) injected slowly into the fill port and allowed to solidify

FIGURE 3.
Parametric images of malignant tumour scans.

FIGURE 4.
Production of a soft tool for the development of a renal artery phantom.
further analysis (figure 3). Professor Donohue’s results showed that small-scale structures (over 4 mm square regions) were consistently characterised, and information useful for identifying ductlike structures, irregular tissue growth and tissue boundaries was enhanced. The next speaker was Paul Barbone (Boston University, MA, USA) who described modulus reconstruction techniques for linear and nonlinear elasticity images. The course then concluded with Peter J. Littrup (Wayne State University, Detroit, MI, USA) who discussed clinical breast ultrasound tomography.

**BASIC SCIENCE SCIENTIFIC SESSION**

That evening I attended the basic science scientific session, the theme of which was image analysis. There were six speakers in this session. Deirdre M. King (Dublin Institute of Technology, Ireland) discussed her novel methodology for development of anatomically realistic renal artery flow phantoms for characterisation of disease within the renal artery. The methodology included the production of renal artery models with varying degrees of stenosis using a 3D printer and an investment casting technique to fabricate the flow phantoms (figures 4 and 5). Deirdre discussed several useful applications of these phantoms, which included quality assurance testing of an ultrasound scanner’s performance and training tools for the detection of renal artery stenosis. Another talk which described a series of phantoms for testing ultrasound scanners performance was presented by Ernest L. Madsen (University of Wisconsin-Madison, Madison, WI, USA). His phantoms were developed for testing intravascular ultrasound systems (IVUS) and were produced using materials that mimic vascular tissues. The phantoms were designed for testing axial resolution, lateral resolution, contrast detail and depth penetration. Ernest suggested that these phantoms will also be useful for comparing different IVUS systems. Evan J. Boote (University of Missouri, Columbia, MO, USA) presented his automated quality control QC software for evaluating ultrasound images of phantoms. He compared his software with a commercially available electronic transducer testing system. The comparison showed that both systems were able to detect flaws on a transducer that had defective piezoelectric elements.

The next morning I attended an ultrasound contrast agent course. The speakers presented a synopsis of the history and current status of ultrasound contrast agents. Also outlined were the bioeffects of ultrasound contrast agents and the risks and benefits of using contrast agents. I presented my research poster in the afternoon (figure 6). My poster outlined the techniques I used to produce and characterise new tissue mimicking materials for use in high-frequency breast ultrasound phantoms. I was not looking forward to the hour-long poster session which is known to be quite intense. However, during the session my poster received a lot of interest from physicists, sonographers and radiologists. I was asked many questions and felt I answered them competently and I received great feedback on my research.

On the last day of the convention I attended a course on acoustic microscopy and a basic science scientific session which focused on tissue characterisation. Unfortunately I had to leave the scientific session early to catch my flight to Madison, Wisconsin.
VISIT TO MADISON

I flew direct to Madison from New York; the flight took less than two hours. Madison is very much a university city, with the campus distributed throughout. The city of Madison is located between Lakes Mendota and Monona and the Capitol building which dominates the city skyline offers scenic views of both (figure 7). The aim of the visit to the University of Wisconsin was to learn a new technique which would enhance the research that I am currently carrying out, and also allow me to use methods and tools not available in my own institution. On the first morning I met with Professor Ernest Madsen; after discussing my research he kindly gave me a tour of the laboratories in the Medical Physics Department. There were separate laboratories for tissue mimicking material production, elastography testing, clinical studies and acoustical measurements.

For the remainder of the visit I carried out a number of tissue characterisation experiments with Meagan Deaner, a research specialist in the Medical Physics Department. Together we performed measurements of speed of sound, attenuation coefficient and absolute backscatter, using state-of-the-art equipment. Overall, the opportunity to visit the University of Wisconsin has been invaluable to my research as the experience gained there has allowed us to reform some of the experimental set-ups in our laboratory.

In all, attending the AIUM conference and the associated visit to the University of Wisconsin was highly informative. I was encouraged by the level of interest in my research and given some great feedback. I would like to extend my thanks to IPEM for partially covering my travel expenses and enabling me to go on this trip.
THE INTERNATIONAL SOCIETY FOR Magnetic Resonance in Medicine (ISMRM) Scientific Meeting and Exhibition is the largest international meeting in the field of magnetic resonance, bringing together over 5,000 delegates from both the clinical and research communities. This year, the meeting took over the Hawaii Conference Centre for a week of educational lectures, oral and poster presentations and plenary sessions (figures 1–3), ranging from molecular imaging probes to the potential for combined imaging modalities such as PET-MR.

MANSFIELD AND LAUTERBUR LECTURES
Robert Shulman (Yale University, New Haven, CT, USA) gave this year’s Mansfield lecture. Professor Shulman gave a fascinating presentation, considering the possibility of correlating brain energy (metabolism) and brain work (neuronal activation and the state of consciousness) using in vivo magnetic resonance spectroscopy (MRS). Professor Shulman presented a wide variety of animal and patient data from MRS studies of the glutamine–glutamate cycle and glucose oxidation. This data illustrated how the high energy consumption, or baseline activity, of the brain at rest correlates with the high level of neuronal activity in the conscious brain, while deepening levels of anaesthesia towards complete loss of consciousness correlate with a decrease in the baseline activity as measured by reduced neuronal firing rates. The lecture was extremely well attended and well received as the opening lecture of the conference.

Al Macovski (Stanford University, Stanford, CA, USA), whose career has spanned multiple fields from colour television electronics to pioneering magnetic resonance angiography (MRA), gave the Lauterbur lecture looking back on the history of MRI and its future potential. His presentation drew on comparisons between the development of x-ray radiography, as x-rays were discovered as an imaging technique, whereas nuclear magnetic resonance (NMR) was originally used for spectroscopy and the application in imaging came much later. His analogy of NMR relaxation mechanisms to the flushing of a toilet drew much laughter; T2 is akin to the flush as the ‘readout’ of the system and T1 to the refilling of the bowl, representing the restoration of magnetisation along the ‘z’ direction. On a serious note, Professor Macovski highlighted the issues surrounding high field MRI and suggested techniques, such as prepolarisation, that could be used to avoid high fields.

PROBING WITH MAGNETIC RESONANCE
Robert Gillies (University of California, Davis, Davis, CA, USA) opened the weekend educational course with an introduction to tumour biology and the stages of the disease. Nine sessions followed, covering the basic pathophysiology of cancer, the role of imaging in preclinical models and drug development, the clinical challenges in cancer, and biomarkers for imaging aggressive cancers. The course covered in vivo, ex vivo and in vitro magnetic resonance spectroscopy (MRS) and imaging with both proton and other nuclei such as 13C, 31P and 19F. Hypoxia, angiogenesis and cellular proliferation were identified as key biomarkers that could be assessed by MRS of metabolic pathways (e.g. via choline), dynamic contrast enhanced MRI (DCE-MRI) and diffusion weighted imaging.

CANCER MR SPECTROSCOPY (MRS)
N. Jagannathan (All India Institute of Medical Sciences, New Delhi, India) and D. Vigneron (University of California, San Francisco, USA) chaired my second educational session of the weekend on the clinical and research applications of cancer MRS. An introduction to the background physics and useful techniques in MRS was given by J. Alger (University of California, Los Angeles, USA) in the ‘Clinical MRS Applications’ session. The utility of MRS in a clinical setting was then emphasised with three lectures addressing the evaluation of brain, breast and prostate cancer. Z. Bhujwalla (John Hopkins University, Baltimore, MD, USA) opened the ‘MRS in Cancer Research’ session with an overview of the main nuclei studied in animal models and their applications, for example 13C and 19F studies of pharmaceuticals and 31P studies of pH. The session continued by addressing the various methods of studying metabolism using MRS, as part of which I. Gribbestad (Norwegian University of Science and Technology, Trondheim, Norway) gave a very interesting lecture on ex vivo NMR using high resolution magic angle spinning (HR-MAS), which provides high resolution spectra from intact tissue samples.
Numerous weekend, weekday and sunrise educational courses covered a wide range of topics, from metabolic studies with MRS to RF coil design.

Both traditional and electronic posters were on show throughout the week, with special sessions dedicated to their presentation proving extremely popular.
SPECIAL SESSION: IN VIVO MR WITH DYNAMIC NUCLEAR POLARISATION (DNP)
Dynamic nuclear polarisation, or ‘hyperpolarisation’, has recently emerged as a technique for increasing the sensitivity of solution-state $^{13}$C MRS by over 10,000-fold or more, enabling in vivo detection of both $^{13}$C-labelled molecules and their metabolites. For example, endogenous substrates such as pyruvate and bicarbonate can be hyperpolarised to examine the metabolic status and pH of a tumour respectively.

Highlighting the progress that has been achieved in metabolic studies using DNP in recent years, a special session at this year’s meeting was dedicated to in vivo studies using this approach, in addition to the many papers presented in other sessions such as ‘Non-Proton MRI’ and as traditional and electronic posters.

The session was opened by Dan Vigneron (University of California, San Francisco, USA) who described the current status of translating DNP towards the first Phase I clinical trials in humans. This overview was followed by a series of talks highlighting the application of hyperpolarised molecules to the study of both cardiac and tumour metabolism. Among the many interesting talks in this session, Helen Atherton (University of Oxford) presented work using hyperpolarised pyruvate to probe metabolism in the hyperthyroid heart, while Angus Lau (University of Toronto, Canada) showed how it could be used to observe effects of ischaemia and reperfusion in the heart. Kevin Brindle (University of Cambridge) showed that the conversion of hyperpolarised fumarate into malate is a marker of tumour necrosis and produces positive image contrast. In a later presentation, Professor Brindle then showed that hyperpolarised bicarbonate can cross the blood–brain barrier and it is therefore possible to use this substrate to image brain pH.

OTHER RESEARCH HIGHLIGHTS
While my primary research interest lies in the DNP field, over the course of the week I attended many other interesting sessions covering various aspects of cancer imaging.

ISMRRM: EDUCATIONAL COURSES AND SCIENTIFIC MEETING
SCOTT HANVEY Beatson West of Scotland Cancer Centre, Glasgow
HONOLULU, HAWAII 18th–24th April 2009

The opening talk in the ‘Molecular and Cellular Probes’ session describing the development of an MR contrast agent to target breast microcalcifications was given by R. Lenkinski (Beth Israel Deaconess Medical Center, Boston, MA, USA). The aim was to distinguish between microcalcifications composed of calcium oxalate, which are indicative of benign disease, and those composed of hydroxyapatite, which are present with malignancy. A lanthanide-chelated bisphosphonate derivative with a high affinity for hydroxyapatite was developed and yielded significant contrast enhancement using ultra-short TE sequences, providing the basis for future high sensitivity MR studies of breast microcalcifications.

Marie-France Pernet (John Hopkins University, Baltimore, MD, USA) gave a talk on her work that aims to identify early metabolic markers of cancer patients suffering from the complex metabolic disorder of cachexia. The resulting weight loss due to loss of body fat is usually a marker of poor prognosis. Dr Pernet showed that while control and cachectic colon cancers grow at a similar rate and have similar fat contents, the cachectic tumours show an increase in total choline, detectable via proton MRS, and the rest of the body has significantly lower lipid concentration. These results indicate that in future it may be possible to use MRS biomarkers to identify cachexia in cancer patients before the onset of symptoms.

TO CLOSE
The Farewell Party was an excellent opportunity to continue networking, while entertainment was provided by Hawaiian musicians and dancers, as well as homegrown conference talent in the T2-star talent show. The meeting was an excellent educational opportunity and a forum for discussion. I gained an essential insight into the current status and future progression of both MRI in general, and hyperpolarisation in particular. In addition to thanking IPEM for funding, I must also thank the ISMRM New Entrant Award scheme and Cancer Research UK.
Ontario, Canada) who reviewed the basic features of gradient coil design and performance. Dr Chronik covered his topic in a question and answer style with questions such as ‘do gradients have to be cylindrical?’ The answer to this is no, they usually are cylindrical, but open MRI scanners use bi-planar gradient coils. Masoom Haider (University of Toronto, Canada) covered MRI of the prostate and mentioned that for staging an endorectal coil is necessary to maximise accuracy even with 3T systems; however, this may change in the future as 3T pulse sequences and surface coil technologies improve.

**SUNDAY 19TH APRIL**

The following day began with an ‘Introduction to Magnetic Resonance Spectroscopy (MRS) techniques’ by Jeffrey Alger (University of California, USA). Dr Alger highlighted that the limiting factor in MRS was the signal to noise, which could be enhanced by averaging signal acquisitions or increasing the volume of interest. Joseph Maldjian (Wake Forest University School of Medicine, Winston-Salem, NC, USA) spoke on the ‘Clinical Applications of Arterial Spin Labelling’ and the importance of using both diffusion and perfusion to detect abnormalities.

The afternoon began with a description of advanced imaging techniques used by Thomas Chenevert (University of Michigan, Ann Arbor, MI, USA) in the management of brain tumours. He described the limitations of conventional imaging in defining the tumour extent and grade and determining a patient’s response to treatment. This led to a discussion of the importance of diffusion, perfusion and MRS in the clinical setting. The use of diffusion MRI in cancer management was reviewed by Doh-Mu Koh (Royal Marsden Hospital, London). Dr Koh spoke on the pros and cons of breath hold versus non-breath hold diffusion MRI with the choice coming down to local expertise. The emerging technology of PET/MRI scanners was covered by Heinz-Peter Schlemmer (University of Tübingen, Germany) to close the Weekend Educational Courses. He spoke of the advantages that MR holds over CT, such as the reduction in radiation dose and cancer risk as well as the improved soft tissue contrast. He also mentioned the possibility of creating a pseudo-CT from the MR data using an atlas of many patients.

**SCIENTIFIC MEETING**

The 17th ISMRM Scientific Meeting ran from Monday 20th to Friday 24th April, bringing together speakers from a variety of disciplines to present work in progress and newly-established technology. Researchers came from the healthcare, commercial and academic professions giving a broad range of perspectives on MRI in medicine. Since it would not be possible to cover all of the sessions attended, the following outlines some of the highlights from the meeting.

**IMAGE ANALYSIS**

Matthias Hofmann (Max Planck Institute for Biological Cybernetics, Tübingen, Germany) presented work on MR-based attenuation correction for PET/MR. Attenuation correction (AC), which accounts for radiation attenuation properties of the tissue, is mandatory for quantitative PET. In the case of PET/MR the attenuation map needs to be determined from the MR image. This is intrinsically difficult as MR intensities are not related to the electron density information of the attenuation map. Dr Hofmann presented methods using ultra-short echo (UTE) acquisition to get signal from bone, atlas registration and machine learning to allow...
prediction of the attenuation map based on the MR image, both for brain and whole body imaging. **Xiaodong Tao** (GE Global Research Center, Niskayuna, NY, USA) described a method for correcting inter-series motion in brain MRI for auto-scan plane planning. He proposed an algorithm that relies on the known position and orientation of the anatomy at the beginning of a scan and uses fast three-plane localisers to update this just before image acquisition. The algorithm finds a rigid transform that best aligns the three plane localisers to the full initial volumetric localiser. This transform is then used to compute a new patient-centric scan plane prescription.

Dr Tao has incorporated this approach in a clinical MR system and demonstrated its usefulness in automatically obtaining consistent imaging planes in brain exams in the presence of motion. Next, a study on brain tissue segmentation using fast T1 mapping was presented by **Wanyong Shin** (Neuroimaging Research Branch, Baltimore, MD, USA). In this study, an automated brain tissue segmentation method based on modelling of individual quantitative T1 values of brain tissues was proposed. To accomplish it, a fast T1 mapping using inversion recovery Look-Locker Echo-planar imaging at a steady state (IR LL-EPI SS) with whole brain coverage was presented. This method is insensitive to instrumental settings and can be used to address specific patient populations and age-dependent groups.

**BRAIN TUMOUR: IMAGING BRAIN TUMOUR TREATMENT AND RESPONSE**

**Gerard Thompson** (University of Manchester) described a method for quantifying the change in apparent diffusion coefficient (ADC) which occurs across tissue boundaries in glioblastoma multiforme on diffusion-weighted imaging. This group discovered the gradient of the change in ADC moving from peri-tumoural oedema into solid, enhancing tumour correlated with the length of survival, whereas the ADC gradient measured from normal appearing white matter into peri-tumoural oedema did not.

**Kyrre E. Emblem** (Rikshospitalet, Oslo, Norway) assessed whether a fully automated, multi-parametric model for predicting outcome in glioma patients from dynamic susceptibility contrast MR imaging can be used as a second reference to pathologic findings. A predictive model based on support vector machines was used to predict outcome in each patient using scatter diagrams and survival status of the remaining patients. This group suggests that their approach provides similar diagnostic accuracy values to histopathology when predicting patient outcome.

Following on from that, a composite model of the parametric response map was proposed by **Craig Galban** (University of Michigan) to predict survival independent of radiographic response in patients with high grade glioma. A parametric response map composite model of the apparent diffusion coefficient and relative cerebral blood flow is predictive of treatment response in glioma patients independent of radiographic response. Perfusion and diffusion MRI were performed on 44 patients pre- and post-treatment. The parametric response map was closely associated to a 10-week radiographic response. A multivariate analysis showed a stronger dependence on the parametric response map than radiographic response.

**HYBRID AND UNCONVENTIONAL SYSTEMS**

**Geron Bindseil** (University of Western Ontario) discussed his work on the first hybrid images from a combined PET and field-cycled MRI system. This differs from other PET/MR scanners where the PET scanner detectors are changed to be compatible with the high field strength in MR. Images from a combined PET and field-cycled MRI...
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The presentations included both invited speakers and proffered papers, showing the high calibre of research that is being undertaken in the region. We have chosen to report on a small selection.

Of particular interest was a presentation by Matthew Guy (Medway Maritime Hospital, Gillingham) on ‘Dosimetry: Current Status and Future Directions. Dr Guy described the lack of personalised dosimetry in therapeutic nuclear medicine in the UK, with great differences in

(FCMRI) system were presented. In FCMRI, it is possible to rapidly turn all magnetic fields off, enabling the use of conventional photomultiplier-tube-based PET detectors. PET data were acquired during MRI sequences in an interleaved manner with a period of several seconds. Johan Overweg (Philips Research Europe, Hamburg, Germany) dealt with the key features of an MRI system for MRI-guided radiotherapy. The linear accelerator (linac)-based radiation source is located on the outside of a cylindrical high-field MR scanner, radiating through the magnet’s cryostat. The coil designs of main magnet and gradient coil provide a gap in the mid-plane of sufficient width to allow the beam to pass through. Magnetic interaction with the linac is minimised by modification of the magnet’s active shielding configuration so that a ring-shaped low field ring is obtained at the location of the field-sensitive parts of the accelerator.

TALENT CONTEST
Another highlight from the meeting was the latest addition of a talent contest known as ‘T2’ Search which formed part of the farewell party on Thursday 23rd April. This included acts demonstrating circular breathing through didgeridoo playing, Scottish country dancing, traditional Indian dancing and a stand-up comedian as well as many others who threw caution to the wind in search of the limelight.

ANNUAL SCIENTIFIC MEETING
OF THE IPEM SOUTH EAST GROUP
DONNA TALBOT AND ROXANNE POTTS Medical Physics, Kent Oncology Centre

KENT ONCOLOGY CENTRE, MAIDSTONE 27th May 2009

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absorbed dose received person to person from fixed or weight-based activities, which may reduce tumour control probability. Using expanded Medical Internal Radiation Dose (MIRD) calculations, quantitative SPECT data, CT data and planning software, a personalised plan was created and adjusted for weight, effective half-life and tumour mass. An optimised tumour dose was calculated accounting for known organ at risk and whole body doses, allowing the practitioner to decide whether the patient was suitable for radioisotope therapy. The talk left delegates reflecting on dose prescription methods within UK departments and possible future improvements.

Nuwani Edirisinghe (University College London) presented results on ‘A Novel Wearable Conditional Neuromodulator for Treating Urinary Incontinence in Spinal Cord Injury’. Mainly caused by neurogenic detrusor overactivity (NDO), incontinence was corrected by transrectal electrical stimulation to the pudendal nerve, activated by monitoring and responding to anal sphincter signals. The stimulation suppressed bladder contractions and the urge to void and contract the urethral sphincter (figure 1). The device was programmed and tested, and found to successfully suppress NDO and increase bladder capacity in patients. This less well known topic demonstrated the diverse range of medical physics research and how it can be used to improve quality of life.

A further interesting presentation was from Jim Warrington (Royal Marsden Hospital, Sutton) on research carried out by James Bedford (Royal Marsden Hospital), entitled ‘Clinical Experience with Volume Modulation Arc Therapy (VMAT): Back to the ARC’. The presentation included a brief history of the development of arc therapy along with a summary of the clinical treatments performed using VMAT. An explanation of the workflow for physicists and quality assurance procedures was included.

There was a focus on the potential benefits of VMAT (figure 2), including the ability to obtain good dose distributions, particularly using non-coplanar arcs, in treatment times comparable and often shorter than those obtained with ‘conventional’ conformal treatments. The talk also covered future developments applicable to VMAT such as the capacity to perform cone beam CT during treatment and the use of electronic portal imaging in in vivo dosimetry. Delegates were left with a feel for what could be in store for future developments in radiotherapy.

Katy Fleckney (Kent Oncology Centre, Maidstone) presented a study of maternal and foetal doses arising from ventilation/perfusion scanning and CT pulmonary angiography (CTPA) during pregnancy. The work arose following an enquiry from a radiologist about the comparative risks of the two most common imaging techniques used for diagnosis of pulmonary embolism in pregnant women. The study compared maternal effective dose, maternal breast dose and foetal dose between CTPA and half dose 50MBq $^{99m}$Tc MAA perfusion scans. The results summarised in figure 3 demonstrate that foetal dose was slightly higher for perfusion than CTPA scans, but this difference decreased over the course of pregnancy. Figures 3 and 4 demonstrate the maternal effective and breast dose, however, was up to a factor of nearly 50 higher for CTPA than perfusion. The results stimulated a change in referral practice, with radiologists preferring to use a half dose perfusion scan where suitable. The talk itself generated considerable discussion at the meeting.

The meeting included a number of other stimulating presentations that certainly left the current authors with renewed enthusiasm both for developing clinical practice and performing research in our own departments. We look forward to next year’s South East Regional meeting which is due to be held at The Royal Marsden Hospital, Sutton.

![FIGURE 2. Potential benefits of VMAT.](image-url)
Absorbed foetal dose for CTPA: mean mAs of 119 (47.2–349), mean DLP of 273 (156–478) mGycm.

Maternal dose for CTPA: mean DLP of 273 (156–478) mGycm.

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RESOLVING OUR DIFFERENCES

The UK’s largest radiology meeting, the UK Radiological Congress, is held annually in June. If you have never been to it or even heard about it, please bear with me while I describe it briefly and explore the lessons it holds.

UKRC hosts the UK’s largest radiology exhibition and an increasingly innovative programme, with clinical and scientific sessions and posters. What is unusual about UKRC, and its sister biennial radiation oncology congress UKRO, is that both of them are organised collaboratively through an umbrella charity (ROC) set up by four professional bodies – ScoR, RCR, IPEM and BIR – representing radiographers, radiologists, physicists/engineers and manufacturers. Whilst UKRO is financially secure, UKRC faces a financial deficit in 2010 partly because the venue (booked in 2005) is now too large, as manufacturers rent less exhibition space.

This potential deficit has been known for some time. The four partner organisations, working under the ROC umbrella, have been working to reshape the Congress and ensure it is profitable from 2011. However, two partners (RCR and BIR) have proposed that UKRC is managed and focused differently, with radiologists organising and BIR managing the event with invited participation from radiographers and physicists, along the lines of the European Congress of Radiology. Without seeing a detailed plan, it is hard to see how this suggestion differs substantively from current arrangements whereby four radiologists and a physicist are responsible for drawing up the programme and the BIR events team manage the Congress. No-one wants to stop holding a UK radiology congress and everyone is concerned to make it financially viable. There is however disagreement as to how this is achieved, disagreement which is highlighting difficulties with charity governance and trustee roles that threaten to break up ROC and undermine collaborative multidisciplinary working not only on UKRC but also for UKRO.

PROBLEMS TO BE SOLVED

This is a high profile example of a situation that we meet often – the resolution of difference. Sorting out differences is demanding. Ignoring differences however builds up resentment, whilst walking away removes the tension but destroys relationships. Resolving or living positively with difference – often called ‘negotiation’ or ‘working at relationships’ – requires changing behaviour, attitudes or both. This is often difficult, which is why the ‘diversity agenda’ is not easy, simple or bounded. Yet from such tensions creativity and growth often spring. In the classic book, ‘Getting to Yes’, Fisher and Ury summarise how to negotiate in a way that develops relationships, where agreement is not about trading outcomes but developing principles. Set the values that you want to follow, then work out together how both parties can benefit. In uncertain times, working together with shared values offers greater resilience and more creative solutions.

As the four partners in ROC look at their differences, the quality of their underlying relationships will be tested. UKRC must change and continue to evolve, and UKRO must be preserved. How we achieve this is, as I write, not clear and the hard work of resolution remains. Most large scientific meetings face similar problems and, as the Institute explores the partnership development of a UK Bioengineering Congress, the final judgement of success with UKRC negotiations will be both the quality of outcome and also what it helps us do more widely across science and health in the UK.

On a personal note, as I finish my time as President I would like to express my thanks. A lot has been achieved under the umbrella of the Institute in the past two years, due to the fantastic work of so many talented and dedicated volunteers. Staff in the Office have been a great support, and they do far more than most of us ever see. I have worked with and got to know more of you better, which has been a real pleasure. My sense of achievement at what I have helped to do is tempered by my awareness that much is left to complete and I look forward to seeing what happens next in the life of the Institute. Being President has been a privilege. I shall miss it.

Keith Ison
President
w

When Steve Bolton contacted me about writing a feature my joyful mood did a quick u-turn when he mentioned the subject: AUDIT! The dreaded ‘A’ word with the power of sending people to sleep as soon as it is pronounced (I must admit I get excited when I hear ‘audit’ as for me, it means easy scanner access).

However, it only take a few months in charge of Scope to realise that you cannot rebut any potential writer or article. Steve’s enthusiasm in his further communications also convinced me that he might be able to produce an article that won’t be soporific. Did he manage to pull it off? Well I think he did a great job, it’s informative, covers the subject and unbelievably for an audit article it is far from dull!

Also in the features, a joint project between the Rehabilitation Engineering Centres at Belfast and Swansea recently received an award for their work on digital seating services and they kindly sent us an article detailing it.

Finally, to continue the heart theme of the last issue, we have a piece on modelling of cardiac activity.

The international news section gathers strength and includes snippets from the States, details of a new WHO initiative, international conferences and a run through of the numerous electronic mailing lists out there.

In the rest of the magazine you will find your essential dose of news, book reviews and conferences.

A special thanks to Sarah Misson-Yates for helping with the book reviews despite being ‘retired’.

Finally, it would not be a Scope editorial without a rallying call. Please keep on sending your articles and flag your members’ news to Andrew. And, if you want to do more we are still looking for editors.

Hope you will enjoy this issue.

MARC E. MIQUEL EDITOR-IN-CHIEF
Cardiac SPECT system with solid-state detectors enhances imaging

For many years, the design of most clinical SPECT systems has been dominated by the Anger gamma camera, which consists of a collimator plus a scintillation crystal coupled to a set of photomultiplier tubes. Image acquisition involves rotating the detector, or dual detectors, around the patient. However, scintillation detectors have a number of disadvantages, including bulkiness and relatively poor energy resolution.

Solid-state detectors have long been used in spectroscopic applications due to their superior energy resolution, but have not been widely adopted for medical imaging applications due to practicality and cost. However, recent technological advances have led to the development of pixelated cadmium zinc telluride (CZT) detector units which are appropriate for medical imaging applications. One such system, called D-SPECT, has been developed for nuclear cardiology applications by Israeli medical device firm Spectrum Dynamics, and researchers at University College London have undertaken a detailed study to compare the performance of the new system with that of a conventional SPECT system (Phys Med Biol 54: 2635).

The D-SPECT system consists of nine blocks with CZT detectors, with a total detector surface of 39 × 157 mm. The compact nature of the CZT detector permits movement that would not be achievable with a conventional Anger gamma camera design, and is capable of ‘region-centric’ acquisition where it is programmed to acquire data mainly from a pre-selected region that includes the heart, thus maximising the acquired counts from this region.

The performance of the D-SPECT system was evaluated and compared to a conventional dual-headed Infinia SPECT system (GE Healthcare, Haifa, Israel) using a number of standard measures, including energy resolution, scatter fraction, sensitivity and resolution. The results showed that, compared to the GE Infinia, the D-SPECT system has better energy resolution (by a factor of ~2), higher sensitivity (by a factor of 5–8 or higher) and a similar spatial resolution. The team is also looking into the use of D-SPECT in other areas, for example oncology.

This story was reported on Medical Physics Web on 22nd May, and further information can be found using the following link: http://medicalphysicsweb.org/cws/article/research/39190

SLN identification using photoacoustic imaging

In patients with breast cancer, it is necessary to determine whether the cancer has spread into the axillary lymph nodes. There are two methods which are currently used for this purpose – axillary lymph node dissection (ALND) and sentinel lymph node biopsy (SLNB) – but both methods are associated with substantial morbidity, and SLNB can involve the patient being exposed to ionising radiation.

A non-invasive alternative to ALND and SLNB which involves photoacoustic (PA) imaging with a carbon single-walled nanotube (SWNT) contrast agent has been developed by researchers at Washington University and the State University of New York, and demonstrated in a rat model (Phys Med Biol 54: 3291).

The mean distance between the surface of the breast and the sentinel lymph nodes is approximately 12 mm, and imaging at this depth requires near-infrared light which means that any contrast agent must strongly absorb at this frequency. SWNTs have a wide absorption spectrum, which makes them good contrast agents in the visible and near-infrared spectral regions. A reflection-mode PA imaging system, with a light source consisting of a tuneable Ti:sapphire laser pumped by a Q-switched Nd:YAG laser, is used to obtain images of the SWNTs.

To demonstrate the use of SWNT-enhanced PA imaging of the sentinel lymph nodes in a rat model, an intradermal injection of SWNTs was administered in the animal’s front paw. Four PA images were acquired at intervals of 25–30 minutes post injection, in which the sentinel lymph node could clearly be seen. The results of this study showed that PA imaging for sentinel lymph node identification with the use of SWNTs as a contrast agent is highly feasible in a small animal model. The method should be easily translated into humans, although the in vivo biocompatibility of SWNTs needs to be thoroughly examined first. The imaging system is currently limited by its slow scanning speed, but using a laser with a higher pulse repetition frequency and an ultrasound array system could accelerate acquisition, and potentially allow real-time PA imaging.

This story was reported on Medical Physics Web on 11th June, and more information can be found using the following link: http://medicalphysicsweb.org/cws/article/research/39446

The figures show a baseline photoacoustic image (left), an image of the sentinel lymph node obtained after injection of SWNTs (centre) and magnified SLN image (right).
Beating heart for development of surgical tools and techniques

The development of new surgical tools and techniques for heart valve repair requires extensive testing and validation before they can be introduced into clinical use. This is usually carried out during in vivo animal trials, but the time and costs associated with such trials is often prohibitive, and a lengthy permission process is required for the use of live animals.

In an attempt to overcome this problem, a team of researchers at North Carolina State University in Raleigh have developed a system involving an explanted heart, in which a computer-controlled pump and the heart’s own valves are used to precisely direct the flow of saline in order to subject the mitral valve to pressure waveforms and flow rates similar to those found in vivo (Ann Biomed Eng 37(4): 651).

The system consists of three mechanical components connected to a freshly explanted pig heart, which is obtained from an abattoir: a left atrial reservoir, an aortic outflow pathway and a computer-controlled positive displacement (PD) pump. The height of fluid in the reservoir and the length of connecting tubes can be varied to simulate different atrial pressures and backpressures against valves (see the photo above).

To demonstrate how the system can be used to quantify mitral regurgitation, a series of experiments were conducted to monitor changes in cardiac output before and after the induction of mitral valve defects. The results clearly demonstrated a substantial reduction in cardiac output when defects were present, and an increase in regurgitant fraction. A subset of the hearts subsequently underwent surgery to repair the mitral valve defects, following which the average cardiac output improved to approximately 84 per cent of the output obtained before defects had been induced.

The explanted heart system has been designed to be an effective and affordable precursor to animal and clinical trials, which could facilitate early studies to evaluate newly-emerging heart repair techniques and devices.

The model has several limitations, such as an absence of cardiac and papillary muscle contracture, which mean that it is not a true physiological representation of in vivo heart function, but the ability to maintain natural valve variability, the open design for surgical evaluations and the consistency of operation all present an improvement upon current ‘explanted valve’ techniques.

This story was reported on Medical News Today on 27th May, and more information can be found using the following link: http://www.medicalnewstoday.com/articles/151493.php

The system contains a real animal heart, allowing surgeons to practice in a realistic environment

IN BRIEF

SLN IDENTIFICATION
A photoacoustic imaging system has been developed to allow the non-invasive in vivo identification of sentinel lymph nodes in patients with breast cancer. A carbon single-walled nanotube (SWNT) contrast agent is injected and images obtained. SWNTs were chosen as they have a wide absorption spectrum and are therefore suited to the near-infrared light imaging required.

SOLID STATE CARDIAC SPECT
A new design of cardiac SPECT system has been developed using solid-state detectors, which provides improved energy resolution and sensitivity compared to conventional gamma cameras. The system uses pixelated cadmium zinc telluride (CZT) detector units suitable for imaging and has been used in nuclear cardiology applications. The team also hopes to use the system in other areas such as oncology.

BEATING HEART MACHINE
A mechanical system containing an explanted animal heart has been developed to allow new surgical tools and techniques to be tested. It consists of a computer-controlled mechanical pump to mimic pressure waveforms and flow rates to those found in vivo. The set-up can be altered to simulate different pressures. This allows surgeons to practice new techniques in a realistic environment before carrying out procedures on patients.
Proton therapy moves into US mainstream practice

This year will see proton therapy become available in the United States for the first time outside of academic centres.

Indiana-based company ProCure Treatment Centers, Inc. is scheduled to open the doors of the ProCure Proton Therapy Center in Oklahoma City this summer. The centre is the first of a growing number of private sector proton therapy facilities planned by ProCure and has been developed in collaboration with Radiation Medicine Associates, a leading radiation oncology practice in the state of Oklahoma, and INTEGRIS Health. Currently, through similar collaborations, ProCure has a second centre under construction near Chicago, Illinois, and three more under development in New Jersey, Michigan and south Florida.

ProCure was founded in 2005 by John Cameron, Ph.D., to make proton therapy more widely accessible to cancer patients. Dr Cameron, previously professor of physics and director of the Indiana University Cyclotron Facility, played a key role in the development of the Midwest Proton Radiotherapy Institute at Indiana University, and is among the pioneers in proton therapy.

In 2008, ProCure opened their Training and Development Center (TDC) in Bloomington, Indiana. The TDC is a treatment centre simulator, consisting of image guidance systems, CT-simulation, treatment planning computers, record and verify system, and proton therapy treatment rooms with functioning control systems and hardware. The only component missing is the actual proton beam accelerator, enabling physicians, physicists and radiographers to receive training ahead of taking up a position. The first training commenced in February, 2009.

The facility in Oklahoma City is equipped with a 230 MeV cyclotron manufactured by Ion Beam Applications (IBAI), Louvain-La-Neuve, Belgium, that will serve four treatment rooms. One room will consist of a fully 360° rotating gantry, another will contain a horizontal fixed beam line, and the other two will utilise ProCure’s innovative and proprietary inclined beam technology, see photo above. The inclined beam can be positioned horizontally or at 60° from horizontal, and it is thought that many sites can be treated with a combination of these beam angles without the cost of a rotating gantry.

The ProCure initiative is an indication of the projected proliferation of proton therapy in the United States in the years to come. It waits to be seen, however, whether reimbursement for proton therapy will change, and the potential impact on this proliferation if it does.

Further information may be found at: http://www.ProCure.com

Siemens Biograph mCT

The Memorial Medical Center in Springfield, Illinois, and the Spectrum Health Lemmon-Holton Cancer Pavilion in Grand Rapids, Michigan, are to be the first two sites in the US to install the Siemens Biograph mCT scanner.

The Biograph mCT is the world’s first molecular CT, and may be utilised both as a dedicated CT and PET/CT imaging system, as well as a sophisticated diagnostic tool for oncology management. This dual capability is achieved through the integration of powerful PET and CT technologies, resulting in a compact system with high-definition PET, time-of-flight technology and CT configurations up to 128-slices.

For more information regarding the Biograph mCT, visit: http://www.medical.siemens.com/webapp/wcs/stores/servlet/ProductDisplay-q_catalogId-e_-1-a_catTree-e_100010,1007660,011525,1011533,1023018-a_productId-e_186792-a_storeId-e_10001.htm

Announcement of these installations was reported on Medical Physics Web on 16th June, and more information can be found by following the link: http://medicalphysicsweb.org/cws/article/newsfeed/39498

Image courtesy of Siemens AG
Global Health Technologies Initiative

The tensions created by advancing technology, limited budgets and critical healthcare needs are evident to all. Since we work in applying technology to healthcare, it will be of interest to learn that the World Health Organization has set up this initiative. Launched by the World Health Assembly in 2007, the WHO Essential Health Technology team has recently begun a two year programme with the following goals:

- establish a framework for the development of National Health Technology Programmes;
- promote innovative technologies impacting on public health.

In addition, a Priority Medical Devices project is developing an agenda for research on devices for high burden diseases.

Certainly, the use of technology in healthcare is receiving attention on an international scale and exciting collaboration is therefore possible. To keep in touch with developments, keep an eye on:

- www.who.int/medical_devices [see ‘access’ tab for Priority Medical Devices];
- www.ihtp.info;
- the Health Technology Management group on www.LinkedIn.com (under development);
- discussions on the Infratech Listserv (mentioned above);
- the IET’s Appropriate Healthcare Technology for Developing Countries meeting (May 2010, date TBC).

ELECTRONIC MAILING LISTS

Over the last few years there has been an explosion in electronic mailing lists, covering all sorts of topics, especially science in medicine. They can be an invaluable resource for clinical scientists and engineers. If you have a problem, be it vendor related, code of practice or legislation the chances are that someone, somewhere in the world, has already solved it, and will be able to help guide you to the answer.

**How do they work?** You can send a question to the mailing list. It is then distributed to all the registered users (list). Users can either reply directly to you or to the whole list in a discussion format. Most lists have options to either receive each e-mail or a daily summary (digest).

The benefits are that you get to see all the questions and answers as the ‘discussion’ takes place. This can provide information on issues with certain pieces of kit or treatment techniques that may never have occurred to you. The discussions can be robust with very experienced practitioners on either side, and are usually insightful. As the lists are international you can also benefit from a bigger picture or other healthcare structure point of view.

<table>
<thead>
<tr>
<th>Mailing list</th>
<th>Details</th>
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<tr>
<td>MEDPHYS</td>
<td>Mostly US radiotherapy based. Send ‘subscribe medphys [your name]’ to <a href="mailto:listserv@lists.wayne.edu">listserv@lists.wayne.edu</a></td>
</tr>
<tr>
<td>Medical-Physics-Engineering</td>
<td>Medical physics in the UK, visit <a href="http://www.jiscmail.ac.uk/MEDICAL-PHYSICS-ENGINEERING">http://www.jiscmail.ac.uk/MEDICAL-PHYSICS-ENGINEERING</a></td>
</tr>
<tr>
<td>DXIMGMEDPHYS</td>
<td>Mostly US diagnostic radiology/mammography issues. Send ‘subscribe [your name]’ to <a href="mailto:dximgmedphys@hermes.gwu.edu">dximgmedphys@hermes.gwu.edu</a></td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>Send ‘subscribe nucmed [your name]’ to <a href="mailto:listserv@largnet.uwo.ca">listserv@largnet.uwo.ca</a></td>
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<tr>
<td>Linear Accelerator Engineers</td>
<td>Send ‘subscribe linac-eng’ to <a href="mailto:majordomo@plato.aristotle.net">majordomo@plato.aristotle.net</a></td>
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<tr>
<td>Radiobiology</td>
<td>Send ‘join radiobiology firstname lastname’ to <a href="mailto:mailbase@mailbase.ac.uk">mailbase@mailbase.ac.uk</a></td>
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<tr>
<td>Biomedical Engineering</td>
<td>Mainly US but very good for detailed equipment advice. Join by paying $15 for two years at <a href="http://bmetsonline.org/">http://bmetsonline.org/</a></td>
</tr>
<tr>
<td>Developing Countries’ Medical Technology</td>
<td>Discussions on technology management, maintenance challenges, equipment donations etc. Send ‘subscribe infratech [your name]’ to <a href="mailto:listserv@listserv.paho.org">listserv@listserv.paho.org</a></td>
</tr>
<tr>
<td>Healthcare Information For All 2015</td>
<td>Promoting discussion on global access to all types of healthcare information (there’s also a specific child health forum). Sign up on <a href="http://www.hifa2015.org/join">www.hifa2015.org/join</a></td>
</tr>
<tr>
<td>Biomedical Engineering Web Forum</td>
<td>UK based, accessed by most EBME departments in the country and some overseas, <a href="http://www.ebme.co.uk">www.ebme.co.uk</a></td>
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<tr>
<td>Linear Accelerator Engineers</td>
<td>To subscribe, send the message ‘subscribe linac-eng’ (with NO name following) to <a href="mailto:majordomo@plato.aristotle.net">majordomo@plato.aristotle.net</a>. The address for submissions is <a href="mailto:linac-eng@plato.aristotle.net">linac-eng@plato.aristotle.net</a></td>
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<tr>
<td>Medical Dosimetry</td>
<td>To subscribe visit <a href="http://health.groups.yahoo.com/group/meddos/">http://health.groups.yahoo.com/group/meddos/</a></td>
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<td>Mould Room</td>
<td>To subscribe visit <a href="http://health.groups.yahoo.com/group/MouldRoom/">http://health.groups.yahoo.com/group/MouldRoom/</a></td>
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### ELECTRONIC MAILING LISTS... CONTINUED

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<tr>
<td>dicomrt</td>
<td>Technical Discussion of the Radiotherapy Objects in DICOM, see <a href="http://groups.yahoo.com/group/dicomrt/">http://groups.yahoo.com/group/dicomrt/</a></td>
</tr>
<tr>
<td>Gel Dosimetry</td>
<td>Scientific and technical discussions on three-dimensional radiation gel dosimetry techniques. To subscribe to the list, send a message to <a href="mailto:postoffice@physci.qut.edu.au">postoffice@physci.qut.edu.au</a> with SUBSCRIBE gel dosimetry in the body of the message. No signature or subject is preferable</td>
</tr>
<tr>
<td>Vascular Brachytherapy</td>
<td>Contact <a href="mailto:Keris@astro.org">Keris@astro.org</a> to be added to the list</td>
</tr>
<tr>
<td>Boron Neutron Capture</td>
<td>Send the message ‘subscribe bnct [your name]’ without the quotation marks or brackets to <a href="mailto:listserv@mitmvamit.edu">listserv@mitmvamit.edu</a></td>
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<tr>
<td>Radiation Therapy</td>
<td>This list is a forum for radiation therapy professionals and students to ask questions, discuss solutions, exchange ideas about equipment, jobs, safety etc. See <a href="http://health.groups.yahoo.com/group/RADIATIONTHERAPY/">http://health.groups.yahoo.com/group/RADIATIONTHERAPY/</a></td>
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<tr>
<td>Clinical Radiation Oncology</td>
<td>To subscribe, see <a href="http://health.groups.yahoo.com/group/radonc/">http://health.groups.yahoo.com/group/radonc/</a></td>
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<td>Radiobiology</td>
<td>To subscribe, send the message ‘subscribe radiobiology [your name]’ without the quotation marks or brackets to <a href="mailto:listserv@jiscmail.ac.uk">listserv@jiscmail.ac.uk</a></td>
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<tr>
<td>Radiation Safety Mailing List (Radsafe)</td>
<td>To subscribe, send an e-mail to <a href="mailto:Majordomo@vanderbilt.edu">Majordomo@vanderbilt.edu</a> with the following command in the body of your e-mail message: subscribe RADSafe</td>
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<tr>
<td>Medical Health Physics</td>
<td>The former medhp-sec and medhp-e lists have been combined into one ‘medhp-sec’ list. To subscribe to medhp-sec, send ‘subscribe medhp-sec’ to <a href="mailto:medhp-sec-request@hps1.org">medhp-sec-request@hps1.org</a> then follow the instructions provided by the mail server to confirm your subscription</td>
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<tr>
<td>Medical Health Physics Newsletter</td>
<td>To subscribe to medhp-sec see <a href="http://www.slac.stanford.edu/cgi-bin/lwgate/MEDHP-SEC/">www.slac.stanford.edu/cgi-bin/lwgate/MEDHP-SEC/</a></td>
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<tr>
<td>Radsafe-EU</td>
<td>This is the English language European equivalent to the international radiation safety mailing list RADSafe. To subscribe to Radsafe-EU send an e-mail to <a href="mailto:majordomo@fz-juelich.de">majordomo@fz-juelich.de</a>. Commands in the subject line will NOT be processed. In the body of the message type the following command lines: ‘subscribe radsafe-eu end’</td>
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<tr>
<td>Radsafe-D</td>
<td>This is the equivalent to Radsafe for German-speaking countries. To subscribe to Radsafe-D send an e-mail to <a href="mailto:Majordomo@fz-juelich.de">Majordomo@fz-juelich.de</a>. Commands in the subject line will NOT be processed. In the body of the message type the following command lines: ‘subscribe radsafe-d end’</td>
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<td>ADAC Pinnacle 3 Users Group</td>
<td>To subscribe, send an e-mail to <a href="mailto:majordomo@explode.unsw.edu.au">majordomo@explode.unsw.edu.au</a> with the following line in the body (not subject) of the message: ‘subscribe pinnacle-users’</td>
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<tr>
<td>CadPlan Users Group</td>
<td>Any CadPlan user can subscribe to the list by sending a request e-mail message to <a href="mailto:owner-cug@majordomo.uni-ulm.de">owner-cug@majordomo.uni-ulm.de</a> with a short statement telling who they are and what their interest is in CadPlan</td>
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<td>Helax-TMS Treatment Planning System</td>
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<td>IMPAC (Record &amp; Verify) Users</td>
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<td>Nucletron Users</td>
<td>Send a subscription request to <a href="mailto:bursters@radonc.ccf.org">bursters@radonc.ccf.org</a></td>
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<td>Theratronics Theraplan Plus</td>
<td>Request a subscription via e-mail to <a href="mailto:tpplistserver@theratronics.com">tpplistserver@theratronics.com</a>. Include in the body of your message the TPS unit number, the e-mail address you wish to use for the subscription, your institution’s name, and your name</td>
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<tr>
<td>Medical Informatics (computer applications in medical care)</td>
<td>To subscribe, send a message ‘SUBSCRIBE MEDINF-L your name’ to <a href="mailto:LISTSERV@VM.GMD.DE">LISTSERV@VM.GMD.DE</a></td>
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<tr>
<td>Artificial Intelligence in Medicine</td>
<td>For more information or for a subscription, e-mail to <a href="mailto:ai-medicine-REQUEST@med.stanford.edu">ai-medicine-REQUEST@med.stanford.edu</a></td>
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## INTERNATIONAL CONFERENCES 2009–2010

### CONFERENCES: EUROPE

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<th>Conference</th>
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| 48th International Meeting of the Particle Therapy Co-Operative Group (PTCOG48) | Heidelberg, Germany 29th September–3rd October 2009 | Info: http://www.ptcog-meeting.de/  
Contact: Juergen.Debus@med.uni-heidelberg.de |
| Young Researchers BNCT Meeting | Mainz, Germany 29th September–2nd October 2009 | Info: http://www.yrm-nct.com/  
Contact: Gabriele.Hampel@uni-mainz.de |
| Annual Congress of the European Association of Nuclear Medicine | Barcelona, Spain 10th–14th October 2009 | Info: https://www.eanm.org/  
Contact: office@eanm.org |
Contact: workshop@mctp2009.org |
| 3rd Langendorff Symposium: Imaging in Radiation Oncology | Freiburg, Germany 22nd–24th October 2009 | Info: www.langendorff-symposium.de  
Contact: hirschle@kongress-und-kommunikation.de |
Contact: im2010@gaec.gr |

### CONFERENCES: REST OF THE WORLD

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<td>40th Brazilian Medical Physics Society Meeting</td>
<td>Sao Paulo, Brazil 8th–12th October 2009</td>
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Contact: neudos11@tlabs.ac.za |
| Combined Scientific Meeting of The Royal Australian and New Zealand College of Radiologists (RANZCR), the Faculty of Radiation Oncology (RANZCR, FRO), The Australian Institute of Radiography (AIR) and The Australasian College of Physical Scientists & Engineers in Medicine (ACPSEM) | Brisbane, Australia 22nd–25th October 2009 | Info: http://www.csm2009.com/ |

### CONFERENCES: NORTH AMERICA

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Contact: education@astro.org |
| 8th International Conference on Dose, Time and Fractionation in Radiation Oncology: Theragnostic Approach to Personalized Multimodality Cancer Care | Madison, Wisconsin, USA 13th–15th September 2009 | Info: http://www.humornc.wisc.edu/icdtf/  
Contact: paliwal@humornc.wisc.edu |
| World Molecular Imaging Congress | Montreal, Canada 23rd–26th September 2009 | Info: http://www.wmicconference.org/dev/  
Contact: ami@ami-imaging.org |
### INTERNATIONAL CONFERENCES 2009–2010... CONTINUED

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<td>51st ASTRO Annual Meeting</td>
<td>Chicago, Illinois, USA 1st–5th November 2009</td>
<td>Info: <a href="http://www.astro.org/Meetings/AnnualMeetings/">http://www.astro.org/Meetings/AnnualMeetings/</a> Contact: <a href="mailto:education@astro.org">education@astro.org</a></td>
</tr>
<tr>
<td>Stereotactic Body Radiation Therapy Training Program</td>
<td>Dallas, Texas, USA 3rd–4th December 2009</td>
<td>Contact: <a href="mailto:Ewa.Papiez@UTSOUTHWESTERN.EDU">Ewa.Papiez@UTSOUTHWESTERN.EDU</a></td>
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### PLANNED MEETINGS 2009

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<th>Venue</th>
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<tr>
<td>User Centred Design: If Only They Had Asked Me I Would Have Told Them How To Make It Better!</td>
<td>15th October</td>
<td>Fairmount House, York When considering assistive technology it can be difficult to identify the important specifications for equipment or systems without including users at the specification and design stage. This meeting will consider the best way to facilitate user involvement when considering assistive technology.</td>
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<tr>
<td>Laser Output Measurement Workshop</td>
<td>16th October</td>
<td>Wessex Specialist Laser Centre, Salisbury Recent MHRA guidance highlights the importance of undertaking appropriate quality assurance checks on laser and IPL equipment. Delegates who attend this workshop will gain hands-on experience in small groups of measuring and monitoring the output from a number of medical lasers/IPL. This will be consolidated by lectures and discussion sessions considering relevant standards and underpinning theory.</td>
</tr>
<tr>
<td>Automating your QA Image Analysis – IQWorks</td>
<td>22nd October</td>
<td>Queen Elizabeth Hospital Postgraduate Centre, Birmingham IQWorks (<a href="http://www.iqworks.org">www.iqworks.org</a>) is a project to provide medical physicists with automated image analysis software for use with DICOM test images such as CT, mammography, radiotherapy and digital radiography. This meeting will showcase the capabilities of the system. It will also demonstrate how to modify existing components and write new routines.</td>
</tr>
<tr>
<td>Practical Networking: Establishing Trust and Responsibility Between IT and Medical Physics</td>
<td>17th November</td>
<td>Queen Elizabeth Hospital Postgraduate Centre, Birmingham This meeting aims to discuss the management of computer-based and networked Medical Devices in a hospital environment, by showing a range of technical solutions and by emphasising the importance of establishing a good relationship between IT and Medical Physics &amp; Engineering departments for successful implementation.</td>
</tr>
<tr>
<td>Brachytherapy – The Modern Era</td>
<td>24th November</td>
<td>Manchester Dental Education Centre Brachytherapy continues to be an important component in the overall management of cancer treatment. The meeting will aim to present these current advances in brachytherapy and should appeal to physicists, clinicians and all staff involved in the delivery of a brachytherapy service.</td>
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<tr>
<td>1st Urodynamics Measurement Meeting</td>
<td>10th December</td>
<td>Fairmount House, York Clinical scientists and technologists have a long standing involvement in the delivery of urodynamics services throughout the UK. This meeting is designed to provide an opportunity to bring together all medical physics professionals working in this physiological measurement specialty, discuss examples of best practice and most of all learn from and network with other NHs colleagues.</td>
</tr>
</tbody>
</table>

Our programme is regularly updated so please visit our website at www.ipem.ac.uk for the latest details. Abstract submission instructions, programmes and registration forms can be downloaded for each meeting.
**IPEM EXAM RESULTS CLINICAL TECHNOLOGISTS**

**IPEM EXAM RESULTS**

Congratulations to the following who have recently been successful in the IPEM Viva Voce examinations for the Clinical Technology Diploma of IPEM [DipIPEM(T)].

<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>Natalie Bebbington</td>
<td>Queen Elizabeth Hospital, Birmingham</td>
<td>Pass with Distinction</td>
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<tr>
<td>Kevin Duffy</td>
<td>Sandwell &amp; West Birmingham Hospitals NHS Trust, Birmingham</td>
<td>Pass with Distinction</td>
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<tr>
<td>Drew Fitzsimmons</td>
<td>Addenbrooke’s NHS Trust, Cambridge</td>
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<tr>
<td>Rachael King</td>
<td>West Midlands Rehabilitation Centre</td>
<td>Pass with Distinction</td>
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<tr>
<td>Katie Woods</td>
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<td>Gemma Beckwith</td>
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<td>Pass with Distinction</td>
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<tr>
<td>David Crosby</td>
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<tr>
<td>Samantha Gardner</td>
<td>John Radcliffe Hospital, Oxford</td>
<td>Pass with Distinction</td>
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<tr>
<td>Daniel Gillett</td>
<td>Addenbrooke’s NHS Trust, Cambridge</td>
<td>Pass with Distinction</td>
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<tr>
<td>Adam Gul</td>
<td>University Hospital Walsgrave, Coventry</td>
<td>Pass with Distinction</td>
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<tr>
<td>Victoria Malysz</td>
<td>Derbyshire Royal Infirmary, Derby</td>
<td>Pass with Distinction</td>
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<tr>
<td>Andrew Penny</td>
<td>University Hospital Walsgrave, Coventry</td>
<td>Pass with Distinction</td>
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**IPEM EXAM RESULTS CLINICAL SCIENTISTS**

**IPEM EXAM RESULTS**

Congratulations to the following who have recently been successful in the IPEM Viva Voce examinations for the Clinical Science Diploma of IPEM [DipIPEM(S)].

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<tr>
<th>Name</th>
<th>Training centre</th>
<th>Result</th>
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<tr>
<td>Jessica Brisco</td>
<td>Royal Hallamshire Hospital, Sheffield</td>
<td>Pass</td>
</tr>
<tr>
<td>Anisha Patel</td>
<td>University Hospitals of Coventry and Warwick</td>
<td>Pass</td>
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<tr>
<td>Mark Tucker</td>
<td>University Hospitals of Coventry and Warwick</td>
<td>Pass</td>
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<tr>
<td>Helen Wheeler</td>
<td>St George’s Hospital, London</td>
<td>Pass</td>
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<tr>
<td>Rachel Dearden</td>
<td>Christie Hospital NHS Trust, Manchester</td>
<td>Pass with Merit</td>
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<tr>
<td>Peter McGookin</td>
<td>Royal Berkshire Hospital, Reading</td>
<td>Pass with Merit</td>
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<tr>
<td>Philip Orr</td>
<td>Forster Green Hospital, Belfast</td>
<td>Pass with Merit</td>
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his book review section showcases four textbooks and a popular science book. Shelley Waugh investigates the *Fundamentals of MRI* while Joanna Finlay takes a closer look at the *Medical Effects of Ionizing Radiation*. Mark McJury considers the best way to write a paper and John Pickett examines *Artificial Sight*. On a lighter note, Simon Stevens delves into the history of the relationship of Pauli and Jung in his popular science review.

Gemma Whitelaw

**Fundamentals of MRI: An Interactive Learning Approach**

The premise of this book is to explain the fundamentals of a rather complex imaging modality to readers in the early stages of their understanding. The book begins with the very basics – defining the key underpinning maths and physics principles and using them to build up to how an image is encoded in each direction. Accompanying the book is an interactive CD containing programs supporting the material in the book.

The book itself is written in an easy-to-read format, with plenty of self-study questions peppered through each chapter, and detailed answers are also provided. At the end of the book there are 150 multiple-choice questions, with answers, for testing the reader’s understanding of the concepts described in the book.

The CD contains interactive programs on which imaging parameters can be ‘tweaked’ in order to see the effect. Initially sceptical (I believed the programs were a little simplistic), I tried using the program in which the repetition time (TR) and echo time (TE) are adjustable when teaching a newly-qualified radiographer about the basics of T1 and T2 weighting. Much to my surprise, she understood immediately after playing around with the values and therefore I have since withdrawn my initial reservations and may recommended that new radiographers want to work through the programs.

My main concern is that there was one main omission from this book – a good explanation of imaging artefacts. While there are passing mentions of them in some of the chapters, none are truly explained in detail and the significance isn’t apparent – in fact there are questions in the final section of the book regarding some artefacts that haven’t previously been mentioned! Obviously this book is meant to cover basics, but I don’t feel an explanation of phase encoding is truly complete without describing why aliasing occurs.

Another small idiosyncrasy is that the book has nine chapters, each going into great detail of the underlying physics and maths, spatial localisation and spin echo imaging. However, the final chapter moves very rapidly covering gradient echo imaging, steady state sequences, bright blood and dark blood imaging and MR angiography! Even as someone who works in MRI I found the chapter to be quite full on!

The book as a whole, however, is good value for money for those just entering the field of MRI and needing a good explanation of the fundamentals. It’s unlikely to be able to be used as sole teaching material, however, for those trying to get to grips with the complexities of MRI; it provides clear descriptions and an interactive CD for hands-on experience of imaging parameters and their effect on the final images.

Shelley Waugh, Ninewells Hospital

**Medical Effects of Ionizing Radiation**

This is a textbook intended for professionals interested in the effects of ionizing radiation on humans. It draws on information from various sources including radiation therapy, accidental exposures such as the Chernobyl incident, occupational exposures and atomic bomb survivors from Hiroshima and Nagasaki. The book deliberately excludes data from animal exposures. Although first published in 1985 it has since been updated, with this edition being published in 2008.

The first chapter serves as an introduction to radiation physics, chemistry and biology. As a physicist I followed the sections on physics but did find some inconsistencies in the text and an incomplete formula relating to equivalent dose. Although the section acted as good revision material, I would not recommend it to anyone without a physics background. The sections on chemistry and biology were much harder for me to follow, having not studied them before.

The second chapter deals with sources of ionizing radiation, namely natural (background) radiation and technologically-induced radiation. Other chapters describe the effects of radiation on genetic material, radiation exposure in utero and stochastic (probability-based) and non-stochastic (threshold-based) effects of ionizing radiation.

Of particular interest is the chapter on carcinogenesis of specific sites which goes into great detail about a range of different cancers. For each type of cancer a general introduction is given followed by specific modifying risk factors (such as smoking) and evidence of cancer induction from radiation exposures (such as occupational or medical). Another interesting chapter deals with the perception of radiation and its psychological effects. It discusses the media’s role in the public perception of radiation and how adverse effects are better documented for radiation than any other noxious agent. It also talks about risk perception and acceptability, such as deciding acceptable levels of medical exposure.

The final chapter deals with the controversial subject of ‘Hormesis’, which refers to the process whereby low doses of radiation may be beneficial. The authors present some of the evidence for this theory but conclude that the data are not strong enough to draw any conclusions, due to potential bias factors and statistical uncertainties.

Overall the book includes extensive references at the end of each chapter, plenty of tabulated data and pictures (some not for the faint-hearted) which illustrate the effects of radiation. On the downside there are lots of acronyms which are described in the text but not in the glossary meaning you have to find their original entry if you are unfamiliar with them. Also as this is an American book some of the terminology caters more to an American audience. Nevertheless, this is an interesting book which draws from a vast range of sources to provide a very detailed account of the effects of ionizing radiation on humans. As well as catering to the medical professional there are aspects which are relevant to other professions such as the legal community and the...
How to Write a Paper

Here is a slim book, which, tardis-like, contains more than you might think it could.

The 150-odd pages are carefully structured into 20 chapters which cover almost every aspect of writing a paper.

The first obvious question is, what kind of paper? The publisher’s blurb on the back suggests this book gives clear instructions on getting published ‘in the biomedical journals’. This becomes clearer still when looking at the types of paper the book addresses: aside from the general discussion, there are chapters on case reports but not technical notes, telling us the intended audience consists of medical/biomedical professionals. The academic contributors are also exclusively from medical departments.

However, that said, there is much valuable advice within the covers.

Chapters 1–7 cover the basic structure of introduction, methods, results, conclusions and referencing. Chapters 8–12 cover the submission process, and differing types of publication: research paper, letter to the editor, case report, review and scientific abstract.

Chapters 13–15 explain the roles of those involved in processing manuscripts: the editor, manuscript assessor and publisher. Chapters 16–18 cover important aspects of authorship, style and ethics. Chapters 19 and 20 give a final overview of the current state of scientific publishing and open access journals.

As you can see from the above chapter topics, this book goes much further than the usual discussions of actually writing a paper. To get published, you also need to understand the process, your role in that process, and the roles of the other people involved. This book certainly offers much food for thought in discussing the entirety of this process.

Importantly, this book strongly benefits from not being written by one or two authors, but having 20 contributors. The editor (a former Chairman of the British Journal of Anaesthesia) has gathered a terrific group of contributors with a wide range of roles including journal editors and publishers, university academics, administrators and librarians, and business professionals.

This small and inexpensive book offers an enormous amount of helpful information on publishing a paper – from the nitty-gritty of the content and style of your manuscript, to explanations of the entire publishing process.

If you want to buy only one book on scientific writing, this might just be it...

Dr Mark McJury, Belfast

Artificial Sight: Basic Research, Biomedical Engineering and Clinical Advances

This book forms part of the series ‘Biological and Medical Physics/Biomedical Engineering’ and emerged from the contributors to the second DOE International Symposium on Artificial Sight. It is not, though, simply a book of proceedings. The chapter authors were encouraged to expand on their work to produce a comprehensive summary of the current research in this field.

The book begins with two introductory chapters, the first from the editors’ group at the University of Southern California on biological considerations for retinal prostheses. This chapter provides an extensive overview of the subject, covering the anatomy and physiology of the eye, testing and measurement, retinal disease and surgical and implant techniques. The second chapter sets out the research aims of the Japanese Consortium for Artificial Retina and details their work in animal models investigating the effectiveness of their new technique for retinal stimulation. Thereafter, the remaining chapters are broadly grouped into sections, each section containing a number of chapters with a unifying theme, but each one independent in its own right.

Under the Human Studies heading a chapter on the effects of visual deprivation on sensory pathways in the brain discusses the implications of sensory plasticity for retinal prostheses and other interventions. Further chapters describe simulated prosthetic vision experiments, which have enabled the practical utility of potential retinal implant therapies to be estimated, and the development of test strategies to assess their efficacy.

The section on Engineering Applications allows the various research groups represented here to expand on their approaches to the engineering challenges of fabricating an implantable retinal prosthesis and its practical application. Issues addressed include overall system architecture, biocompatibility, power transmission, image processing, telemetry and preliminary clinical trials. A Stimulating Electrodes section groups together contributions dealing with the electrochemical characterisation, tissue interactions and materials science of electrode design. A further section on modelling is a significant theme comprises two chapters addressing the physical limitations and electromagnetic effects of implant design (resolution, stimulation thresholds, heat dissipation and so on). The last part of the book is made up of chapters addressing the biological response to stimulation. These cover in vitro and animal studies of the tissue responses to both retinal and intracortical stimulation and also the optimisation of stimulation strategies. A very interesting and readable review of the electrophysiology of natural and artificial vision forms the final chapter of this section.

This is a handsomely produced (and quite weighty) book of some 380 glossy pages with numerous colour illustrations. Its aim is to summarise the state-of-the-art research in this area and this it does comprehensively. There is, however, enough introductory and background material included to make the material accessible, even to a relative stranger to the field. The organisation of the
Deciphering the Cosmic Number: The Strange Friendship of Wolfgang Pauli and Carl Jung

This book, the fourth by Arthur Miller, follows in his familiar theme of exploring the intellectual stress and strife surrounding some of the greatest scientific developments of the modern day, coupled with the drama of the on–off relationship between science and the arts. Having already dealt with the unlikely pairing of Einstein and Picasso in a dual biography, Miller now turns his attention to Wolfgang Pauli and Carl Jung. Pauli was, of course, one of the great theoretical physicists of his time, responsible for the development of quantum mechanics and the Pauli ‘exclusion principle’. Carl Jung is meanwhile famous, of course, for... well, something to do with psychology.

It turns out that, although both were remarkable academics in their respective fields, Pauli and Jung exhibited maverick tendencies. Jung turned away from the direction of his mentor Freud, and his interest in mythology and symbolism saw him labelled him as an occultist. On the other hand there is Pauli, who despite his brilliance suffered deep depressions. He regularly ended up in bitter arguments with his colleagues and, particularly after the breakdown of his marriage, often resorted to the solace of alcohol. It is at this low point where he seeks the psychoanalytical help of Carl Jung. Jung and Pauli strike up a long-lasting friendship which enables them both to broaden their thinking and together discuss what Jung calls ‘the no-man’s land between physics and the psychology of the unconscious’. It is through these long discussions that Jung is able to articulate his theory of synchronicity, where seemingly unrelated events occur simultaneously in a meaningful way. These events reveal a collective framework and, for Jung, this gave evidence of the ‘collective unconscious’ lying at the depths of the psyche.

What is perhaps most enjoyable in this book is Miller’s fascinating and well-documented account of the individual growth and development of Jung and Pauli to the height of their respective careers. Pauli’s research lies central to the development of quantum mechanics, which matured throughout the 20th century following progressive contributions from a number of notable physicists. Miller does well to recreate the mood of the time and the interactions between Pauli, Heisenberg and Bohr and Jung and Freud respectively. Pauli’s relationship with Jung features in the second half of the book and focuses on Jung’s analysis of a series of vivid dream sequences experienced by Pauli. The life of Pauli dominates the majority of the book and it is evident that the relationship of Pauli and Jung is probably not strong enough to sustain the book as a whole. In fact, the theme of deciphering the ‘cosmic number’ does not feature until the end of the book and lies in a discussion of the number 137 – the value of the fine structure constant, a fundamental number which lies at the core of the universe. Jung’s theories offered Pauli a way to understand a deeper meaning behind the magical number 137, leading into the realms of mysticism, alchemy and symbolism.

Miller, as a scientist, takes time to describe scientific theories for the non-scientific reader. He explains key developments, and the progression of scientific thought in a time of conflicting ideas and changing beliefs. Miller is an excellent writer, with a fluid and well-balanced writing style. This book is ideal for anyone with a keen interest in the history of science or anyone who would like a starting point into the work of Carl Jung. For any reader seeking the answer to life, the Universe and everything, read ‘The Hitchhiker’s Guide to the Galaxy’ instead.

Simon Stevens, St Bartholomew’s Hospital, London

DECIPHERING THE COSMIC NUMBER: THE STRANGE FRIENDSHIP OF WOLFGANG PAULI AND CARL JUNG
ARTHUR MILLER

Just Published!

Prostate Brachytherapy in Clinical Practice by Stephen E.M. Langley, Robert W. Laing and Jyoti Shah (Springer) markets itself as an essential text for urologists, oncologists, radiation physicists, specialist nurses and family medicine practitioners to become conversant with the developing technique of prostate brachytherapy.

Nuclear Medicine Applications and Their Mathematical Basis by Michael Goris (World Scientific Publishing Co.) reviews the principal applications of nuclear medicine by focussing on the mathematics behind them. A good book for those interested in a deeper understanding of nuclear medicine applications.

The Handbook of Anatomical Models for Radiation Dosimetry by George Xie George Xu, Keith F. Eckerman, John G. Webster and Slavik Tabakov (Taylor and Francis) presents anatomical models in order to evaluate the strengths and applications of each. It investigates the models’ developments over time and how modern practices have impacted upon them.

Digital Radiography: An Introduction for Technologists by Euclid Seeram (Cengage Learning) is a text particularly suitable for courses in radiographic imaging; it may also be suitable for the newer technician or radiographer as it describes all aspects of digital radiography.

Basics of Biomedical Ultrasound for Engineers by Haim Alzhari (IEEE Computer Society Press) is suitable for university engineering courses and researchers in the field. It encompasses a wide range of topics including acoustic fields, focussing devices and conceptual definitions of waves.

Gemma Whitelaw
St Bartholomew’s Hospital