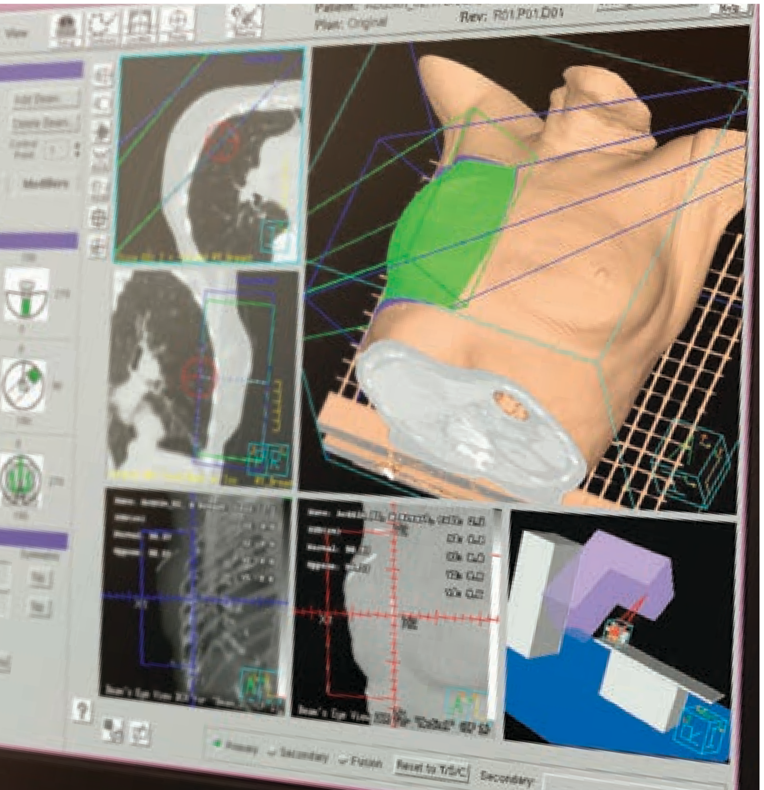
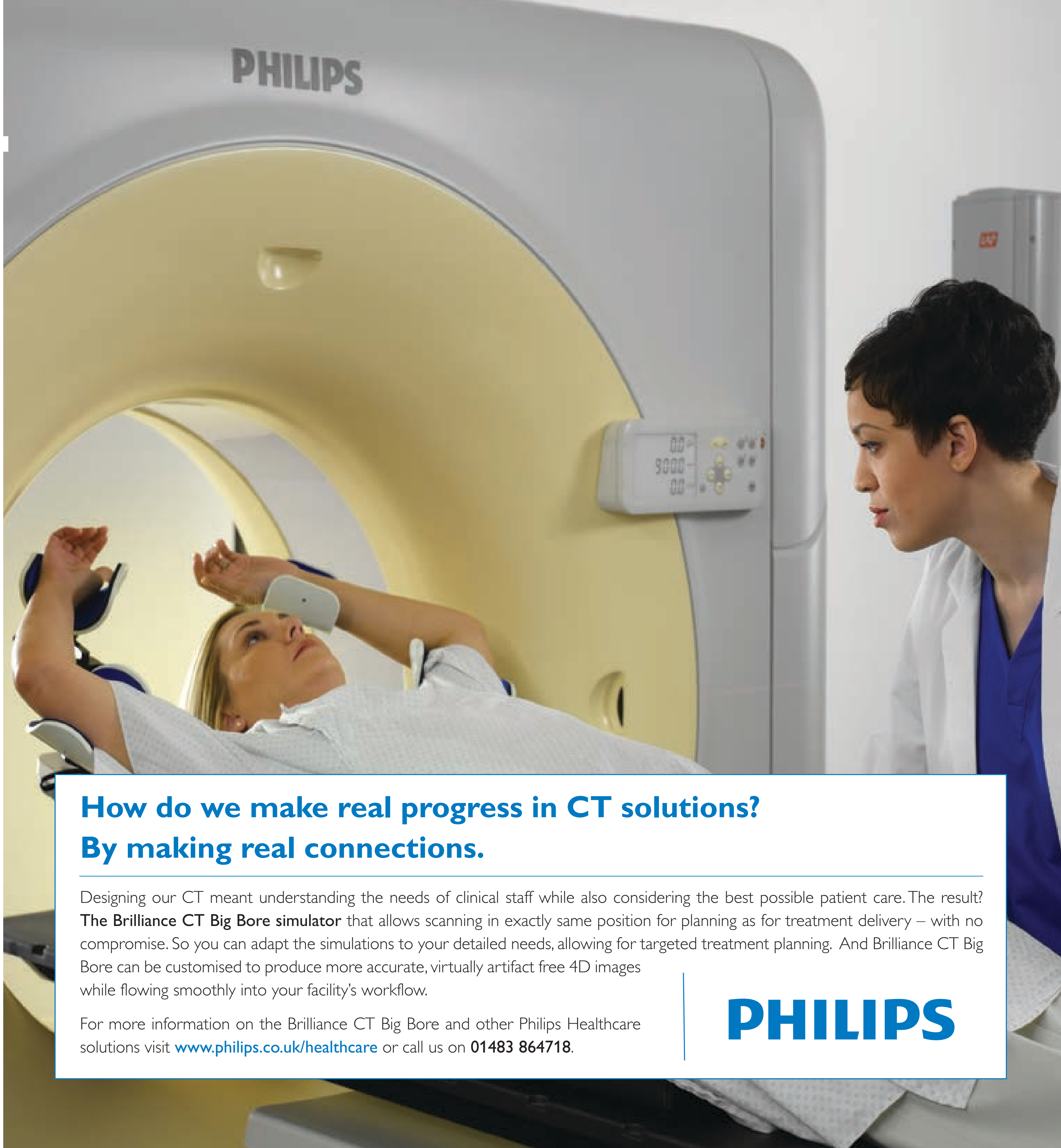
IMAGING & ONCOLOGY

For imaging and therapy professionals

2013

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{4} EDITORIAL

Look on this year's issue of *Imaging & Oncology* as therapeutic. In the wake of the sobering *Francis Report* from the Mid Staffs enquiry[1] published earlier this year, which catalogued numerous examples of complacency, neglect and insensitivity, the work in this publication demonstrates healthcare at its best. All the authors care passionately about what they do, which ultimately affects the quality of care received by the patient. Certainly, not all papers here are suggesting that things are perfect. Quite the opposite; Probst and Gallagher complain that radiographers need to conduct more research. Why do they care? Because more high quality research will benefit that Very Important Person at the centre of our work. Similarly, consider the two articles related to educational issues. Both voice considerable concerns with the current or shortly anticipated state of play, but still this is because they value the education of students, knowing that patient care starts at recruitment and continues, post-registration, with CPD. Perhaps, however, their concerns are unfounded. After all, the newly formed Health Education England, which is responsible for overseeing education for every staff member of the NHS in England, promises to 'deliver a better health and healthcare workforce'[2].

For this publication, I try to find authors to represent as many of the different specialities of imaging and oncology as possible, whether it be magnetic resonance imaging, endoscopic imaging or brachytherapy, for example. This year's issue offers a further dimension in that three of the papers discuss imaging methods, which are common enough in their own right, but conducted in unusual or extreme circumstances. Rutty and Morgan emphasise the importance of offering CT autopsy services in the UK and highlight challenges faced by the workforce. Leason gives a graphic insight into imaging services at Camp Bastion, and suggests that experiences and advances in techniques there, are likely to benefit civilian populations in the future. Tomasini takes us to Haiti and describes with equally stark clarity some of the differences between Western world and developing world radiography; I for one shall never complain again about a dripping tap in my ultrasound room ... Of course, these services are not the only examples of 'extreme or unusual' uses of imaging either. It is likely that applications and locations will continue to diversify – but only if sustainable funding can be found. Collaborations like the one described by John Lilley (p12) may be one way of securing funding. Equally, innovative managers and researchers are likely to find other ways.

This issue includes further contemporary papers on mammographic technique, adaptive 4D radiotherapy, cardiac imaging, and the next steps in electronic health databases. Let me know if there's a topic you'd like to read about next year.

HAZEL EDWARDS

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FOREWORD {5}

I am honoured to have been invited to write the foreword for this prestigious publication. It is always one of the highlights of my year to have access to the thoughts of the most forward thinkers in the professions involved in clinical imaging and radiotherapy.

Each year we see constant change and innovation despite – or possibly because of – the lack of money and investment in services, but you will see as you browse these pages, articles on innovation in the NHS, CT autopsy, cardiac NM, imaging in Haiti and adaptive 4D radiotherapy to name but a few. There would appear to be no lack of enthusiasm for new developments in the articles we have here. I hope you will all take the time to read and consider if the good practice being shared can be used within your own service.

It has been an interesting time for the NHS; in England, the Health and Social Care Act continues to challenge, and the second *Francis Report* will change the way we provide services, as we are reminded why we are all here and start to re-embed the values of the NHS at its conception, putting the patient first. Much work remains to be done; we need more investment in radiotherapy, we need to undertake more research, we need to continue innovating, we need to keep up with the advances in technology and we need to remember whilst we do all this – that patients are people and require much more from us than the ability to take the image, report the image and give the treatment. They need to see that the healthcare provided in the UK is second to none and we as professionals must take on this responsibility. To that end, enjoy reading this edition of *Imaging & Oncology 2013* and may it inspire you.

JACKIE HUGHES
PRESIDENT
THE SOCIETY AND COLLEGE OF RADIOGRAPHERS

{6} PLACEMENT LEARNING IN PRE-REGISTRATION RADIOTHERAPY PROGRAMMES IN ENGLAND:

IS THERE A NEGATIVE CULTURE IN RADIOTHERAPY CENTRES?

HAZEL COLYER

Concerns about high attrition from pre-registration radiotherapy programmes in England have existed for some years especially because it is higher than other health professions, including diagnostic radiography.

In 2010/11 the figure was 35.6%[1], which means that, of approximately 360 student places commissioned, 120 will not qualify. Previous studies have identified that poor experiences on clinical placement make a significant contribution to a student's decision to leave their programme[2,3]. Not only is this unacceptable per se, but predicted growth in the radiotherapy workforce to meet service demand is put at 39% by 2016[4]. In response to this crisis, the National Cancer Action Team (NCAT) commissioned a project early in 2012 to identify and understand the causes of attrition, with a particular focus on the clinical learning environment in radiotherapy (RT) centres in England.

The project used a qualitative methodology within an audit and service evaluation context involving an online audit of radiotherapy centre policies and practices using Survey Monkey™. The audit tool was developed from recognised standards for placement learning[5,6,7,8]. The outcomes were tested and verified through a 20% sample of site visits and interviews. In addition to the radiotherapy service managers (RSMs), an opportunistic sample of 36 qualified radiographers from all grades was interviewed, together with nine students. A complete response was obtained from English radiotherapy centres (N=50).

These outcomes were triangulated through telephone interviews with programme leaders from the 10 higher education institutions (HEIs) that offer pre-registration radiotherapy programmes. The resulting data were themed and discussed at a meeting of RSMs, practitioners with responsibility for student education, and HEI programme leaders, to produce draft recommendations. Finally, students were invited to a conference to articulate their claims, concerns and issues about placement learning[9] and comment on the draft recommendations before they were finalised.

"Radiotherapy services must improve"

A comprehensive picture of the culture of learning support and development existing in many radiotherapy centres emerged and raised some serious concerns, which will be discussed here. Evidence from the project suggests a negative and backward-looking organisational culture that is detrimental to students, practitioners and, by implication, patient care. In the wake of the recently published *Francis Report*[10], which calls for massive cultural change in healthcare practice, radiotherapy services must improve.

The Senses Framework

The Senses Framework was developed and used originally to improve care in gerontological nursing settings using a relationship-centred approach[11]. The framework has been validated subsequently by staff engaging with the 'Leading into the Future' programme to structure students' engagement with staff during placement and to create an environment where all are valued[12,13]. The senses referred to are: sense of security, sense of continuity, sense of belonging, sense of purpose, sense of achievement and sense of significance. The meaning of each was interpreted by patients, staff, family carers and students. For example, the sense of security for students was described as 'the freedom to learn and explore roles and competences within a supportive but enabling environment', while for staff it was 'to feel free from physical rebuke, threat or censure, to have secure conditions of employment and to have the emotional demands of the work recognised and to work within a supportive culture'. As a tool to promote relational practice and improve work cultures, it provides a sound framework for analysis in this article.

Organisational cultures in English radiotherapy centres

Culture is the term used to capture the diverse expression of norms, beliefs and values that is evident in organisations and groups. Although a somewhat intangible concept, it can be discerned in the published policies and procedures of the organisation and observed in the way the members of the organisation – staff and students in this case – relate to one another. Radiotherapy centres are complex places with demanding workloads; a potent mix of high-tech environments treating large numbers of people with cancer at all stages of the disease. The staffing profile is diverse, comprising doctors, physicists, nurses and other workers, in addition to radiographers. The RT centre is also a place for the formation and development of staff and therefore has learners at all levels and stages of progress among its professional groups.

It will be argued that the evidence from the Improving Retention Project[14] suggests that the culture in relation to learning support and development of radiographic students and staff is not acceptable and requires significant improvement.

Radiotherapy centre policies and procedures

The audit tool comprised 31 statements in three categories; organisational policies and procedures, relationships with HEI(s) and radiotherapy centre practices. It used a four point Likert scale for responses: strongly agree, agree, disagree, strongly disagree. The Survey Monkey™ software allocated a score of 1 for strongly agree, 2 for agree, 3 for disagree and 4 for strongly disagree. In the summary of responses, each statement was awarded an average score. Therefore, an average Likert rating of > 2.0 implies a tendency to disagree. For each standard, respondents were asked to make a comment if desired and to state whether evidence for the response could be provided if requested.

The Organisational Policies and Procedures category comprised five statements relating to the deployment and management of students in placement and their visibility in radiotherapy centre policies and plans. The mean average score for this section of the audit was 2.01, with a range of 1.92-2.46 and the category also demonstrated a lack of available evidence ranging from 38% to 74%. The dissonance between agreement and evidence in this part of the audit tool was explored during site visits and it became apparent that the mean average score should, in fact, be higher since some RSMs had agreed that policies were in place within the audit tool but, when questioned, stated that they were not written policies.

It is concluded that the audit demonstrates a lack of written policies about the numbers and deployment of students on placement and, with regard to the ways in which students may expect to be treated, they are generally not identified specifically, but are viewed as being covered by local Trust policies, especially in regard to equality and diversity. This lack of visibility in policies and procedures, together with the lack of policies to manage deployment and placement overcrowding, suggests that there is little recognition of the specific needs of students as a group. It can be inferred that they are not regarded as significant within the overall culture of the radiotherapy centre. The lack of visibility impacts negatively on students' sense of security, belonging and significance to the work of the radiotherapy centre.

"THE PROFESSION SEEMS TO HAVE LITTLE INSIGHT INTO THE VALUE OF THEORY, KNOWLEDGE AND SKILLS IN LEARNING AND ASSESSMENT"

Student support and assessment

There were four statements in the audit tool relating to how students are supported in practice to develop their skills and competences in radiotherapy. The tool used the terms mentor and mentorship to describe this process. The mean average score for whether mentors have formal training was 1.58 and none disagreed. However, the comments made by 14 centres indicate that the term 'formal' has been interpreted widely, with only one HEI known to insist on mentors having undertaken an academic module to facilitate practice learning and assessment. For the others, it is usually a day's training that takes place at the HEI or in the radiotherapy centre and may, or may not, be carried out with the direct involvement of university staff. Most mentors receive regular updates (mean average score 1.88). Comments made by RSMs indicate ambivalence about the need for updating and suggest that staffing levels may not permit it to happen.

It is especially instructive to note the variety of terms used to describe those who give learning support to student radiographers; mentor, clinical assessor, supervisor, appraiser, practice educator. Additionally, only 39 centres agreed that students always have a designated mentor. When this topic was explored during visits, it was observed that mentoring is frequently viewed as a team responsibility and, therefore, students are regularly supervised by staff who do not have any special training or additional qualifications. In addition, mentoring is sometimes separated from assessment to promote objectivity and there is variation in how assessment of practice takes place. The importance of dedicated practice educator roles in managing students' placement learning was referred to frequently, although the role is not evident in all centres, neither is it secure.

The audit results demonstrate clearly that there is no consistent view of mentoring and assessment. There is no consensus about terminology or process, although there is a prevailing view that, in order to be objective about clinical assessment, this process should be separate from mentoring. The views expressed by centre staff are generally not based on any evidence since the profession seems to have little insight into the value of theory, knowledge and skills in learning and assessment. Where staff have undertaken a formal academic module, they are unequivocally positive about the benefits to themselves and students. This dilemma has been the subject of considerable debate in nursing and midwifery for many years. A compelling body of evidence has been built up on how the two roles are perceived and enabled by appropriate education and training of mentors[15,16], but the radiographic profession as a whole appears to have insulated itself from this.

Students were highly critical of the arrangements for student support and assessment in centres and of the structure of placement learning and variation in the quality of learning opportunities. One student stated that the quality of learning 'completely depends on which radiographers you are working with', a statement that all students at the student conference agreed with. They also questioned the rationale for the perceived disparity between programmes, especially in clinical contact time. These differences in contact time and placement structure are difficult to defend since they are generally not evidence-based. However, it can be said that they do little to encourage students' sense of continuity and belonging through feeling part of a defined group with a clear, valued, agreed role and identifying with a community of peers.

Overall, it is contended that systematic and relational support for student learning is given a low priority by radiotherapy centres. As such, it is difficult for students to feel a sense of purpose, achievement and continuity when the arrangements for supporting practice learning are not on a firm, consistent footing. This inconsistency is a blot on the profession and out of step with all other non-medical health and social care professions. For example, nursing and midwifery insist on designated, qualified and regularly updated mentors for all students and placement providers are required to keep a live database of mentors, which is inspected during quality monitoring visits. Other professional groups, such as occupational

"THERE ARE STAFF WHO DO NOT VALUE HAVING STUDENTS, ARE PERCEIVED AS DIFFICULT TO WORK WITH AND WHO STUDENTS AVOID"

"Preceptorship, CPD and clinical supervision are the architecture of a mature learning culture beyond registration"

therapy and social work, would not permit a student to be placed in setting without a suitably qualified fieldwork educator or practice teacher.

Perceptions of bullying and marginalisation – managing expectations

As might be expected, the statement in the audit tool: 'All practitioners are committed to having students and promoting their wellbeing', scored positively with a mean average of 1.6. Yet, despite this, the comments revealed ambivalence and contradiction. One manager stated that some staff see this as an optional extra and highlighted the culture change needed, while another suggested that there is scope for improvement. In one case the manager stated that supporting student learning and development is included in Personal Development Review objectives. This issue was probed during visits and there was general acknowledgement that, while many staff enjoy having students and recognise their professional responsibility in this regard, there are staff who do not value having students, are perceived as difficult to work with and who students avoid.

Students were clear that they believe that there is a causal link between student attrition and the experience of bullying behaviours in radiotherapy centres. This is a topic that provokes defensive responses from practitioners who charge students with over-reacting and not being able to accept the discipline of the radiotherapy team delivering complex treatments under considerable pressure on Linear Accelerators (LAs). In addition, there is evidence of cultural differences in how students are perceived and whether their expectations are legitimate and deserve to be met. A clear distinction was apparent within the data between those staff who empathise with students who are learning in a complex and difficult clinical environment and those who believe that students expect to be 'spoon-fed' and fail to grasp that patient care is at the heart of the radiotherapy service and not them.

The term 'LA fodder' was used by some to describe the work of Band 5 practitioners and it was suggested that students' expectations needed to change to be brought into line with this (derogatory) view. The *Francis Report*[10] is clear about the harsh and uncaring cultures in too many healthcare organisations. The *Report* casts it as a 'top down' problem, with managers who are under pressure to meet performance management targets, creating a similar ethos among those they are responsible for, that reaches right down the organisation to the lowest and arguably the most vulnerable levels, ie student practitioners.

There is no doubt that, in 21st century Britain where a rights-based culture prevails, individuals prioritise their perceived entitlements. In the case of student radiographers this needs to be acknowledged as translating to a personalised learning approach, which takes account of them as individuals deserving of respect and having differing learning needs. They themselves expressed a desire for honesty and openness. For students to feel a sense of significance and achievement, it cannot simply be a question of treating all students as if they were inferior clones of one another who should be able to discern what they should be doing and how to behave, or take the consequences.

Preceptorship, clinical supervision and continuing professional development (CPD)

The audit tool asked specifically whether clinical supervision as recommended by the College of Radiographers' guidance document[17] was embedded within radiotherapy centres. This is a system of professional support that has been widely adopted among health and social care professions to give practitioners the opportunity to engage safely in reflective practice as a means of coping with the daily stresses of clinical practice and to assist in developing their careers. The mean average score for this statement was 2.22, indicating that clinical supervision is not viewed as a positive system for staff support and development, and interviews confirmed that it has not been implemented widely.

During visits, staff were also asked about structured preceptorship programmes for newly qualified radiographers and it was clear that this too is variable, as is the opportunity for all practitioners to engage with CPD activities. There is a perception that funding for CPD for radiographers is lacking and arrangements within Trusts for accessing the non-medical education and training budget were often not clear. The concept of personal professional development review planning as part of the managerial appraisal process seemed to be a work in progress for many centres. Few radiotherapy centres have embraced the four-tier professional structure[18] that entails respect for a culture of learning across the whole organisation. There was evidence of advanced practice in many radiotherapy centres, but this is not embedded systematically within centre plans.

Preceptorship, CPD and clinical supervision are the architecture of a mature learning culture beyond registration. They should follow on naturally from a supportive learning environment for students and demonstrate a learning culture that values all staff. The absence of these processes from many RT centres suggests that improving the culture is seen neither as a priority nor a problem.

The culture of support for learning

A closer analysis of the evidence from the audit undertaken in this article shows that the culture of support for learning in English radiotherapy centres is weak and patchy and the learning environment for many students on placement is impoverished. It is in need of both systematic and relational attention. The Improving Retention project recommendations[14] are intended to address the problem of student attrition in pre-registration radiotherapy programmes in England through a range of systematic, organisational, operational and professional measures.

However, when these issues are viewed from the perspective of the organisational culture in radiotherapy centres, it is contended that they demonstrate that the norms, values and beliefs expressed within the audit responses are consistent with Francis' view[10] that the culture of compassionate care has been compromised. It is apparent that there is much painful work to be done, firstly in acknowledgement of the deficits and then in claiming ownership of the problems that are evident and taking the steps necessary to remedying them.

Hazel Colyer works independently as an Education And Management Consultant after a long career in radiotherapy and higher education. She was Dean of Health and Social Care at Canterbury Christ Church University until 2011 and was awarded the FCR in 2012. Currently she is an Associate Editor of the scientific journal Radiography.

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{12} CLINICAL IMPLEMENTATION OF THE AGILITY™ MULTILEAF COLLIMATOR

JOHN LILLEY

"OUR GOAL IS TO OFFER ALL PATIENTS THE BEST RADIOTHERAPY AVAILABLE"

In January 2008, the radiotherapy service for West Yorkshire transferred from Cookridge Hospital, at the edge of Leeds, to the new Bexley Wing of St James's Hospital, close to the heart of the city. This purpose-built cancer centre is a Public Finance Initiative (PFI) funded facility that includes the building and a Managed Equipment Service. The equipment provided includes 10 Elekta AB (Stockholm, Sweden) linacs that are now used to treat around 7500 patients per year. Our goal is to offer all patients the best radiotherapy available.

Developing new techniques and introducing new technology requires a lower patient throughput than our PFI linacs can offer. The new centre provided an opportunity to develop a research partnership between Leeds Teaching Hospitals Trust (LTHT), Leeds University, the Yorkshire Cancer Centre Appeal and Elekta. Core funding was provided by an investment by the Trustees of the LTHT Charitable Foundation, which helped secure industrial contributions and other external grants. From this, two further linacs were purchased, in addition to funding for staff, to drive clinical and technical programmes of research and development. The unique way that the research facility is funded allows us to use extended treatment slots for trouble shooting during development. The research linacs are therefore used to introduce state-of-the-art techniques to a limited number of patients in a very controlled clinical environment, followed by adoption of the tried and tested techniques on the rest of the linac fleet.

One of the research linacs has been used mainly for clinical projects, involving treating patients on trials, and to develop and implement the most up to date treatment techniques. It has been instrumental in helping to establish ourselves as the leading centre in the UK for lung stereotactic ablative body radiotherapy (SABR). The second research linac has been used for technical developments, working in close partnership with Elekta. One of the key development projects was the linac treatment head with the Agility™ Multileaf Collimator (MLC).

Material/methods/results

For Elekta, the development of Agility™ began many years ago. Our involvement with the project started in 2008 with initial Monte Carlo modelling of the new design followed by the installation of an early prototype. Monte Carlo modelling is a mathematical way of using random numbers to simulate the direction and energy of the radiation. At this time, the new head had yet to be given a name, and was locally referred to as 'Edith' or '2MLC'. As with any new industrial development, there was a need for confidentiality during the development phases, formally controlled by non-disclosure agreements.

One of our key roles was to characterise the beam-shaping performance of the MLC with baseline measurements. In addition to Elekta, we worked with colleagues at the Royal Marsden and Ghent University Hospital on the Monte Carlo model of the new head and subsequently on measurements on the prototype. These included MLC leaf specification measurements to confirm models of leaf radiation leakage and penumbra[1]. Whilst the new control system was being developed, initial field-shaping with the prototype MLC was carried out manually. Software was written in-house to support this work to both define and measure field sizes using an electronic portal imager, which is a world away from the convenience that clinical users have. At this early stage in a product's development, there are many repeat measurements to be made and often, lots of issues with the developing systems uncovered. This is the point of the testing and evaluation work and helps to ensure that when the product is commercially released there are very few problems. Design and performance issues with the prototype were fed back to Elekta and this information was used to inform the development of the final production model.

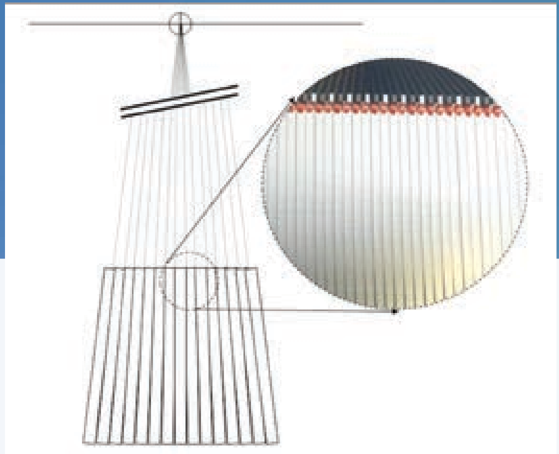


Figure 1: The Agility™ MLC design showing the rubies.

The unique features of the Agility™ are its 160 inter-digitating tungsten-alloy leaves, with a width projected at isocentre of 5mm. These leaves are mounted on Dynamic Leaf Guides (DLG) that can move up to 15cm. Relative to the guides, the leaves can extend up to 20cm. The leaf sides are flat (not tongue-and-groove). Instead, the leaf sides are designed to tilt away from the direction of beam divergence, which reduces radiation leakage between adjacent leaves in much the same way as a tongue-and-groove design would do *(figure 1)*. It is important to keep radiation leaf leakage low as it means that the radiation can be concentrated to the cancer cells rather than normal tissue.

There is also a single set of diaphragms, which move perpendicular to the MLC leaf direction and can over-travel the central axis by up to 15cm. The diaphragms are of a novel, sculpted design to reduce their overall weight, yet still provide optimum shielding at the edges of fields and for the leaf-gaps between opposing leaves uninvolved with the delivered field shape. Both leaf and diaphragm ends are rounded.

The leaves are able to move by up to 3.5cm/s and the DLG at 3.0cm/s. This gives a possible combined leaf-speed of up to 6.5cm/s. The jaws can also move at 9.0cm/s. This compares with typical leaf speeds of 1.0 to 2.5cm/s for other commercially available MLCs. The improvement in leaf speed can have significant advantages for the delivery of the most complex treatments such as intensity-modulated radiation therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT).

Instead of controlling the leaves using visible light and light reflectors positioned on the leaf tips, UV light is used with the Agility™. Small rubies are located at the end of the leaves, and these rubies fluoresce under UV exposure *(figure 1)*. It is this fluorescence that is detected by the new optical control system. In addition, visible light is used to provide a light-field. The melinex window at the exit of the beam at the bottom of the head is also a UV light filter, so that the field appears green coloured.

My role as the lead for the Treatment Planning developments came relatively late in the project. I was involved in the planning aspects for the first treatments. One of our strengths in Leeds is that we are excellent multidisciplinary team workers, built on the experience and successes of previous projects. Regular meetings were set up with the different staff groups, each being brought in to play as and when required during the progress of the project. With this particular project, there were also regular telephone conference calls with the Elekta project team, so that we were kept informed of the development process, along with the set-backs and progress a project of this scale inevitably encounters. For a long time the release date for Agility™ was set as 1 April 2012, with no-one involved in the project wishing to be fooled by any last-minute surprises. (Only much later did we realise the 1 April fell on a Sunday that year…)

Prior to releasing the Agility™ as a CE (1) marked clinical product, Elekta performed a process of clinical validation. This involves using the new head in all the many different ways that it might be used clinically, in realistic treatment scenarios, some of which were quite different to clinical practice in place in Leeds. A helpful spin-off from this was that we had on-site Elekta applications experts for the linac, Mosaiq (Record and Verify System) and Monaco Treatment Planning System. Over the course of the project we had many meetings and discussions about how these three systems communicated and operated with each other. Our testing in a clinical environment was critical to the success and completion of the project.

We had much debate about the types of patients that we were going to treat with Agility™. We did not have a backup machine, which meant that in the event of scheduled or unscheduled down-time, certain categories of patients would require a backup plan, along with all the associated overheads that that entails. We investigated the options of delivering a relatively straight forward palliative plan, a head and neck VMAT plan or a lung VMAT SABR plan. Finally, to meet the target date of 2 April, the palliative plan was used.

During the last weekend in March 2012, we upgraded the research facility to the latest version of Mosaiq, v2.41 and completed all commissioning and verification checks. To be able to treat a patient, however, the Agility™ needed to be formally CE marked, so we had to wait until this was officially confirmed on the morning of Monday 2 April. Shortly afterwards, the first clinical plan was delivered successfully. We became the first centre in the world to treat using Agility™, just pipping to the post our colleagues in James Cook Hospital, Middlesbrough by a matter of hours!

Obviously, treating simple plans was not making full use of the new technology. Therefore, work continued on developing more complex delivery techniques, including a single-sided head and neck VMAT class solution. This was an extension to a project that we first started, developing VMAT using a standard MLCi2, 80-leaf MLC. We had found that VMAT using Agility™ with two partial arcs, planned using Monaco, could reduce the exit dose through the contralateral normal tissues, including the parotid gland and larynx. In comparison, the standard 3D conformal plans would often compromise on planning target volume (PTV) coverage in order to constrain and minimise dose to these normal tissues.

Our first clinical VMAT plan had a single 60Gy dose level to a left-sided PTV. The diagonal line on the coronal view *(figure 2)* indicates a floor rotation was used in order to reduce doses to the eyes and also to avoid the shoulders. It is also possible to see the good sparing of contralateral normal tissues and the excellent conformity of the prescribed dose around the PTV. For this patient, the treatment time was four minutes shorter than it would have been for a standard 3D conformal plan and a minute shorter than it would have been for VMAT using the previous generation of MLC (MLCi2).

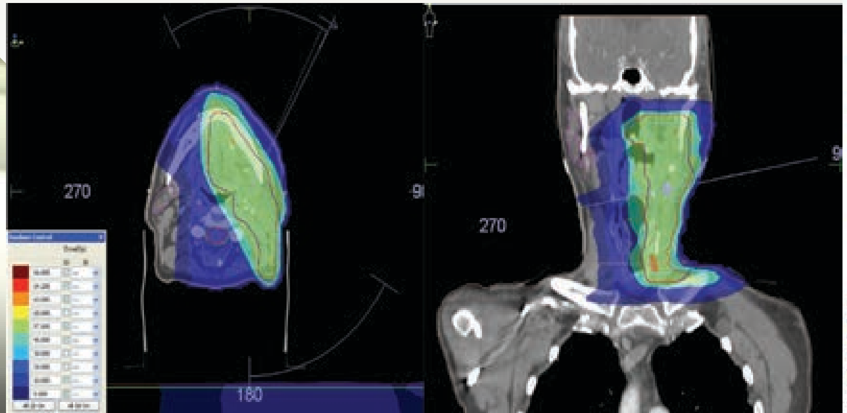


Figure 2: The dose distribution for the first VMAT head and neck plan.

Leeds was the first centre to treat non small cell lung cancer (NSCLC) SABR following the guidelines of the UK SABR consortium[3] and we have now treated well over 400 patients using this technique. The high dose deliveries (54-60Gy) in a small number of fractions (3-8) can be achieved only with a very careful patient verification process, usually involving several online 3D Cone Beam CT (CBCT) scans during the treatment session. Our standard technique involves seven coplanar conformal fields. We were keen to update this technique to VMAT to reduce the time a patient would spend in the treatment position. Following an evaluation of many different VMAT approaches, we identified a class-solution involving a 200 degree VMAT arc, which gave the best compromise between PTV dose coverage and low dose to the organs at risk *(figure 3)*. The beam-on times obtained are also significantly shorter, reducing by approximately five minutes the time patients need to be in the treatment position. Previously, repeat CBCT would sometimes be required during SABR treatment delivery, to check the patients' setup between beams. However, this is now proving to be unnecessary with the VMAT technique[2].

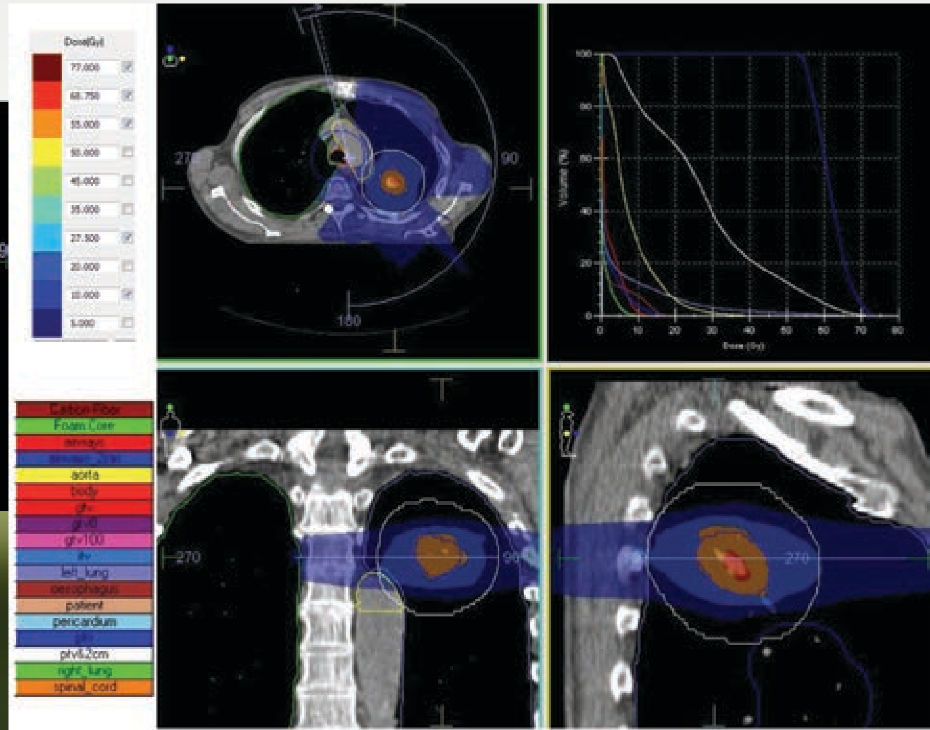


Figure 3: The dose distribution and dose volume histogram for the first Agility™ VMAT SABR lung plan.

Benefits

Our research and development collaboration with Elekta has been very successful, resulting in real benefits for our patients. Elekta are provided with a clinical environment to test their new equipment and receive valuable feedback about their products prior to general release. For us it has meant that we have been able to use new equipment and software as soon as it is available and so offer our patients the most up-to-date radiotherapy. We can also evaluate software prior to clinical release to test all the new features that have been promised. The disadvantage is that we spend time identifying problems during testing that are subsequently corrected ready for when others get to use the software clinically later on. This takes significant resources so should not be undertaken lightly.

The future for patients at Leeds

Our collaboration with Elekta has meant that we have been able to offer faster treatments on the research linacs to a limited number of patients with lung, prostate or head and neck cancer. We will soon have VMAT available on our PFI linacs so will be able to offer this type of treatment to many more patients. The quicker treatments will mean that we can treat more patients each day on the PFI linacs, as well as providing a much better patient experience. Having the experience of VMAT on the research linacs will mean that converting from IMRT to VMAT on the PFI linacs will be simpler. In the future, we would hope Agility™ features in the replacement programme of the PFI linacs so that we could fully realise the advantages that this work has shown. Although this article has concentrated on the VMAT and the Agility™ aspects of our collaboration, we have also worked on other projects such as image guided radiotherapy, which help ensure that the planned doses are delivered more accurately to the patient[4].

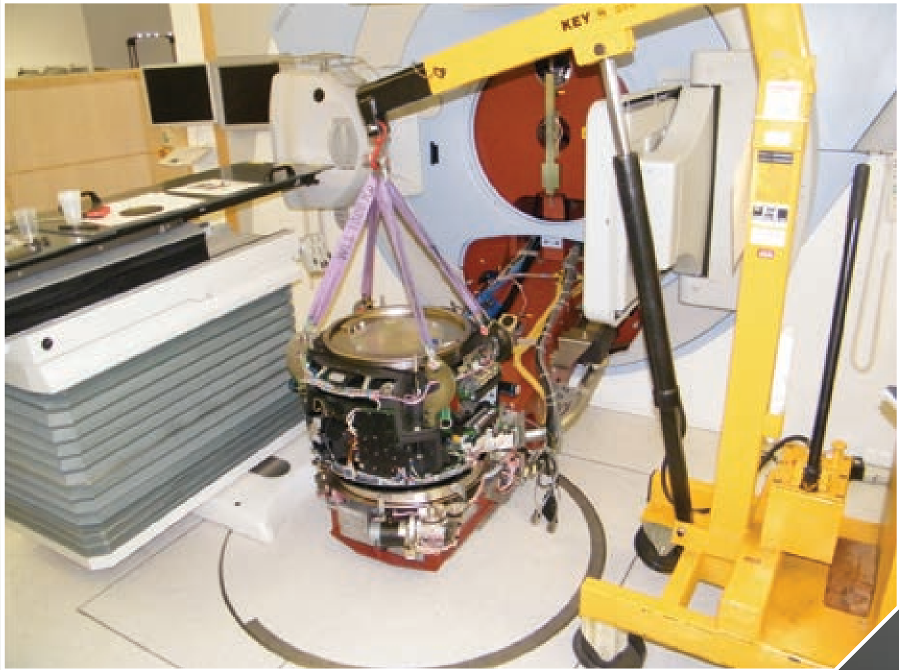
We are currently working on projects that we expect to demonstrate further reduction in treatment times whilst reducing doses to normal tissue.

Conclusion

None of what we have achieved would be possible without the high level of commitment and dedication shown by all the staff who have worked on these projects. Having a responsibility to develop and pioneer new treatment methods is not without difficulties, but is also very rewarding. We anticipate that with further collaboration with Elekta we will continue to refine treatment pathways and improve outcomes for our patients.

"Radiation can be concentrated to the cancer cells rather than normal tissue"

Figure 4: The Agility™ head being lifted onto the linac.



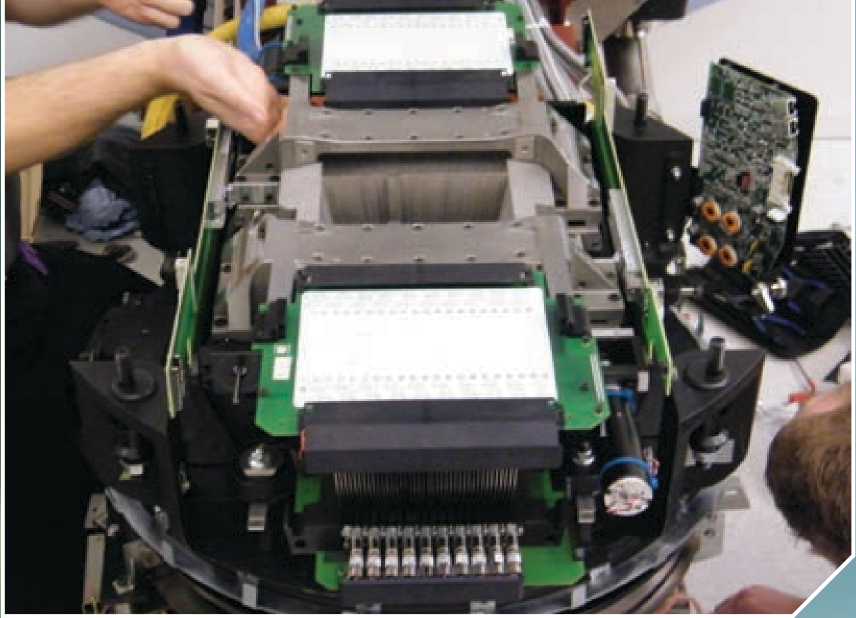


Figure 5: Technicians working on the Agility™ leaves.

Figure 7: The prototype covers that were changed in the general release.

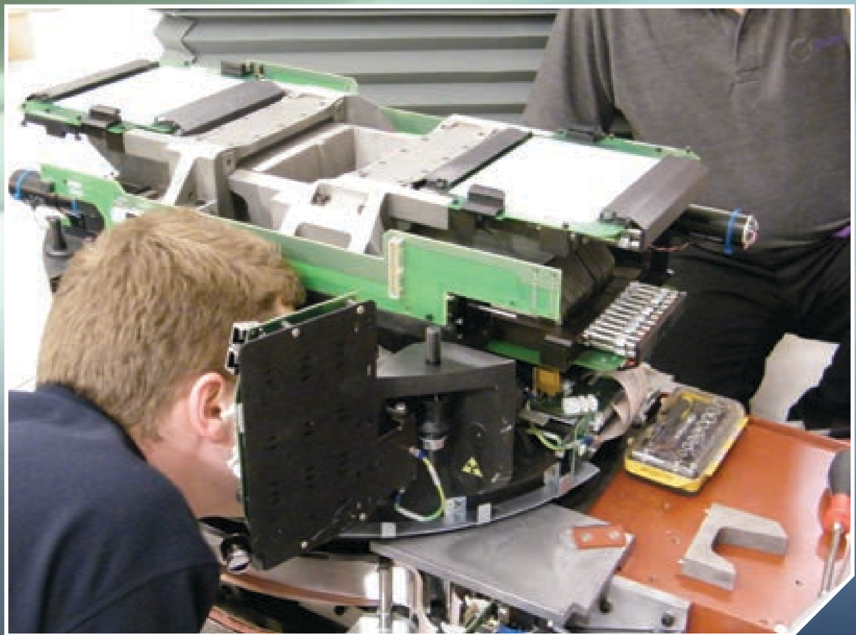


Figure 6: Inspecting the leaves.

"The beam-on times obtained are significantly shorter"

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John Lilley has worked in medical physics since 1989, starting in radiotherapy in Birmingham in 1992 before moving to Sheffield and then to Leeds in 1999, where he is lead in Treatment Planning (including R&D). In 2008 he led the project to introduce 4DCT and the SABR for lung. He is currently working on projects to expand the availability of IMRT and VMAT to all patients who might benefit.

Footnote

(1) The CE mark is recognised as a declaration by the manufacturer that the product meets all provisions of the relevant legislation including those relating to safety. The CE mark also indicates that the product can be freely marketed within in the EU without further control. Further information can be obtained from http://www.mhra.gov.uk/home/groups/es-era/documents/publication/con007490.pdf

"THE IMPROVEMENT IN LEAF SPEED CAN HAVE SIGNIFICANT ADVANTAGES FOR THE DELIVERY OF THE MOST COMPLEX TREATMENTS"

Elekta's Versa HD™ System Sets New Standard of Radiotherapy for Cancer Patients Worldwide

During a live global event on March 1, Elekta announced the launch of Versa HD™, an advanced linear accelerator system designed to improve patient care and treat a broader spectrum of cancers. Featuring highly conformal beam shaping and tumour targeting, Versa HD also introduces new capabilities designed to maximize health care system resources and deliver highly sophisticated therapies without compromising treatment times. Elekta has achieved CE Marking, allowing European medical centers to employ Versa HD for their patients with cancer.

Versatility to deliver better treatments to more patients

Versa HD gives clinicians the flexibility to deliver conventional therapies to treat a wide range of tumours throughout the body, while also enabling treatment of highly complex cancers that require extreme targeting precision. As an integrated treatment system, Versa HD offers the versatility to address today's growing cancer management challenges.

"In Versa HD, we incorporated technologies that would provide an immediate impact to patient health and quality of life," says Elekta's President and CEO, Tomas Puusepp. "Versa HD represents another market-leading innovation from Elekta, and reflects the best thinking of Elekta's technical experts and our clinical partners."

Integrated with Elekta's Agility™ 160-leaf multileaf collimator (MLC), Versa HD provides ultra-precise beam shaping – critical for maximizing the dose to the target while also sparing surrounding healthy tissues. Importantly, this high targeting accuracy is available over a large field-of-view, permitting delivery of high-definition (HD) beams to a wide spectrum of complex targets. Historically, high-definition beam shaping often was mechanically limited to only small target therapies. Versa HD with Agility overcomes this challenge, now empowering clinicians to deliver extremely precise beam contouring for both small and large targets.

Unprecedented combination of High Dose Rate delivery and rapid MLC leaf speed

Capable of delivering radiation doses three times faster than previous Elekta linear accelerators, Versa HD harnesses the ultra-fast leaf speeds of Agility MLC. With this groundbreaking combination, clinicians can now – for the first time – fully exploit higher dose rate delivery, potentially enabling even greater capabilities for sophisticated therapies, including stereotactic radiosurgery (SRS), stereotactic radiotherapy (SRT) and volumetric modulated arc therapy (VMAT).

Versa HD™ is not available for sale or distribution in all markets.

For more information please visit:

www.VersaHD.com

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4D ADAPTIVE RADIOTHERAPY

HELEN A MCNAIR

Radiotherapy treatment planning and delivery has increased in complexity in the last 30 years. Two dimensional (2D) planning using orthogonal films and subsequent verification with port films was standard practice in the late 1970s. The introduction of computed tomography (CT) scanning for radiotherapy planning had major impact in the 1980s but the subsequent verification, although made more efficient with electronic portal imaging (EPI), remained two dimensional.

3D imaging at the time of treatment was not available until the development of in-room cone beam CT[1], CT on rails[2], and tomotherapy[3]. The efficacy and efficiency of these technologies is under intense investigation and include national trials in the UK such as CHHiP and IMPORT (1) and national and international recognition for the need for guidelines regarding implementation[4-6]. However, the next step in the progress is to consider the 4th dimension, time.

Definition of adaptive radiotherapy

Adaptive radiotherapy was first described by Yan et al in 1977 as 'a radiation treatment process where the treatment plan can be modified using a systematic feedback of measurements'[7]. The National Radiotherapy Action Group (NRAG) described adaptive radiotherapy 'as allowing the treatment set-up and dose delivered to be verified and then changed as necessary during a course of treatment'[8]. There are many other definitions and although they vary a little, the consistent principle is to adapt to patient and/or tumour changes over time. These changes can occur during the time interval between CT and treatment, the treatment course or the treatment delivery. Adaptive radiotherapy aims to compensate for these changes and maintain the prescribed dose to the target whilst ensuring the dose to normal tissues is not increased. 4D adaptive radiotherapy includes improved tumour localisation, improved imaging at CT planning and the use of treatment images to review and adapt the plan[6]. The scope of this paper is the use of treatment images for adaptive radiotherapy. Current status will be outlined and potential for the future explored.

Adaptive methods

Patient specific margins

The conventional approach to patient set-up changes are the use of offline or online correction protocols with appropriate planning target volume (PTV) margins derived from population based data[9-11]. An adaptive approach creates a patient specific margin determined from the individual's set-up displacements, ie the geometrical deviations from the planned treatment. This has to be based on observations during the initial treatments because until then it is not possible to establish the individual patient's set-up displacements.

This approach was first retrospectively investigated using EPIs, hence assessing only the patient set-up in three site specific groups of patients; those with cancers of the head and neck, or lung or pelvic region[7]. The accuracy of predicting the random and systematic error from the initial fractions was considered. A set-up margin of 3-4mm was possible in 42% of head and neck and 37% of lung patients and a margin of 4-6mm possible for 40% of pelvic patients. The study also simulated adaptive radiotherapy for patients with prostate cancer, using the first eight fractions to predict the systematic errors and one third of patients' prescription doses could be escalated by 15%. However two thirds of patients were not suitable for higher dose escalation because of large positional displacement, illustrating the importance of individual rather than population-based margins.

The use of CT scanning rather than EPI provides soft tissue information and the first studies involving repeat CT scans (acquired on the first five

"The 'plan of the day' approach has been shown to be clinically feasible with potential for improved outcome"

days of treatment) evaluated the potential of patient specific margins for patients receiving partial bladder radiotherapy[12]. An adaptive treatment volume encompassing the maximum excursion of the bladder tumour on each of the five scans with a one centimetre margin was created, and repeat CT scans acquired immediately before or after treatment assessed the impact. Although the adaptive technique reduced PTVs by 40% this was not reproduced in all patients or in all treatments; 5% of repeat CT scans (one scan each from five different patients) showed the bladder tumour outside of the PTV. The potential for further investigation into predicting which patients would require adaptive was demonstrated because tumours located in the bladder dome were more likely to move outside the adaptive PTV, than tumours located in the lower half of the bladder.

An interesting study in patients with prostate cancer compared an offline EPI strategy using bony anatomy, a daily online study using gold markers and an adaptive study using CT scans acquired the first week to determine a composite volume + 5mm (during the first week 10mm margins were used)[13]. There was no difference in the dose delivered to the prostate using online imaging compared with the adaptive planning. The adaptive plan also delivered a higher rectal and bladder dose, possibly due to the margins used. However, PTV margins which are too small can increase biochemical failure even with online verification[14]. The adaptive process must be evaluated carefully in context of the entire pathway, for example the tumour localisation technique, margins and frequency and type of imaging.

Library of plans

The implementation of in-room 3D imaging, in conjunction with remote couch correction, enabling online verification using soft tissue anatomy, has allowed online methods of adaptive radiotherapy to be explored. This involves creating a library of plans, rather than the one conventional CT scan and selecting a 'plan of the day'. The most common, and probably the most appropriate site investigated is bladder cancer and one of the first studies used three PTVs with increasing superior borders of 5mm, 10mm and 15mm[15]. One of these plans was suitable for 75% of the patients and an average of 31 +/- 23cm^3 of small bowel was spared. More recently a planning study demonstrated an advantage of a 'plan of the day' approach (four plans with margins of 5, 10, 15 and 20mm) compared to (i) a composite plan created from the first three fractions and (ii) a conventional 15mm margin plan[16]. The composite arm of the study could be criticised for using only the first three days of imaging to create the plan, however further analysis showed that although using the first five days would have improved target coverage, the rate of geometric miss would have remained greater compared to the plan of the day.

A more individual approach was developed by using repeat scans at different time intervals to establish the pattern of bladder filling[17]. Patients were scanned at 0, 15 and 30 minutes after voiding and a 15mm margin was used on all CT scans to create three PTVs. Cone beam CTs were acquired daily and a need for adaptive planning was demonstrated in 51% of patients. Although 27% of treatments were not suitable for any adaptive plan, if the closest adaptive plan was chosen the coverage was improved compared to the conventional plan. In contrast to the study by Pos et al mentioned above, no predictive factor was related to patients who required adaptive planning. However, in Pos et al's study the patients were treated with a full bladder to simulate partial bladder radiotherapy, and had an empty bladder in Lalondrelle et al's study. A subsequent publication regarding the clinical implementation of Lalondrelle's study demonstrated a much improved mean coverage of the clinical target volume by the 95% isodose of 99%, with a mean reduction of PTV by 40%[18]. The plan of the day approach has been shown to be clinically feasible with potential for improved outcome, and will be evaluated in a UK national trial, opening in autumn 2013.

The plan of the day approach has concentrated on whole bladder treatments where patients require an empty bladder. A plan of the day approach where a full bladder is required for a partial boost may be more difficult to implement, because of the difficulty of consistently reproducing a full bladder. Two studies have published initial results with a full bladder. The first required seven patients to drink 400ml water 30 minutes before the scan. Six intensity modulated radiotherapy (IMRT) plans were created with PTV increments from 5mm to 3cm and 99.5% of the treatment used the plans with 5mm to 15mm margins[19]. Patient tolerance and bladder volume consistency was not reported. The second study investigated five patients who were asked to drink 200-300ml of water (this was later increased to 800ml) 3-15mins before the first CT scan[20]. Three to four repeat CT scans were acquired at 15-30 mins time intervals and an average of three IMRT plans were created. Three of the five patients were able to maintain reproducible bladder volumes. However, there were four fractions on two patients where the bladder was too large for any PTV. More investigation with particular attention to bladder filling and reproducibility is required. A study has commenced at the Royal Marsden NHS Foundation Trust, which is investigating the feasibility of such an approach (Huddart R, personal communication).

"Adapting the treatment plan in response to changes is a more reactive approach"

Replanning

Adapting the treatment plan in response to changes is a more reactive approach and the majority of the studies have focused on patients receiving radiotherapy for head and neck cancer. In an early study the benefit of adaptive radiotherapy at the simplest level, ie using daily online verification and bony anatomy compared to alignment with shell marks was demonstrated[21]. Using shell marks, the median dose to the parotid gland increased by 5 to 7Gy in nearly half the patients, but with online registration using bony anatomy this increase was reduced but did not disappear. This demonstrates the effectiveness of registering to bony anatomy in a clinical site with effective immobilisation, but also illustrates the possibility of internal anatomy changes occurring during treatment. A further step is to adapt to compensate for soft tissue anatomy changes. In patients with head and neck cancer, changes can occur prior to radiotherapy because of adjuvant chemotherapy or during radiotherapy due to weight loss or tumour shrinkage. Adapting the radiotherapy to compensate for these changes requires replanning, or rescanning at least, but the frequency and timing remains a matter for debate. The ability to predict the patients susceptible to changes would enable efficient use of resources but this does not seem possible. The first study investigating weight loss in patients with head and neck cancer treated with IMRT used repeat CT scans acquired at weeks two, three, four and five during radiotherapy. Although a mean relative weight loss of 9.7% (± 3.5%) of the original weight was found, there was no correlation with tumour volume changes. The greatest weekly reduction of volumes occurred at week two and was 3.2% for CTV1 (gross tumour volume and involved lymph nodes) and 10.5% for CTV2 (areas at risk for microscopic disease)[22].

Other studies have also shown similar volume differences and weight loss changes. In a group of 23 patients treated with IMRT using three repeat CT scans acquired during treatment, an average weight loss was 13lb (8.3%), which corresponded with an increase in dose inhomogeneity[23]. Again no single positional or anatomical variable predicted the need for a re-plan despite the fact that in 61% of patients the dose homogeneity would have improved by replanning at fraction 11 or 22[23].

The first prospective clinical adaptive trial investigated a two stage adaptive approach for oropharyngeal cancers[24]. The first stage involved online daily registration using bony anatomy and in-room CT images. The second stage involved recalculating IMRT plans at least weekly and more frequently if required. All patients required at least one replan, the median time for which was at the 16th treatment fraction, with a corresponding CTV shrinkage of 5%. Just over a third (36%) of patients required a second replan. Underdosing did not occur with image guided radiotherapy (IGRT) or adaptive radiation therapy (ART) treatments and the mean parotid dose sparing was improved. The median weight loss was 8.4% and, in contrast with the above studies, was correlated with percentage reduction in parotid volume, but only at the time of the first ART plan, not at the end of treatment. In addition, patients who presented with large high-risk CTV demonstrated greater response in CTV by the end of treatment. Toxicity was comparable to IMRT treatment. This group recently reported further data confirming that one replan at the median of fraction 16 showed the majority of dosimetric improvement, compared to IMRT aligned to mask or bone or two replans[25].

Similar to head and neck cancer, changes in lung cancer tumour volumes affect dosimetry during treatment[26] but, in addition, the baseline shift can have a significant affect in dose delivery[27]. The majority of adaptive approaches for patients with lung cancer focus on the IGRT aspect with daily online image guidance to compensate for this. The importance of the baseline shift was demonstrated when several adaptive approaches were compared[28]. An offline adaptive strategy, for which replanning was modelled after four initial measurements, reduced substantially the required CTV to PTV margin from 9.7mm to 4.5mm ± 2.4mm (range 1.9 to 9.1mm). An online daily correction strategy resulted in a further decrease from 4.5mm to 2.9mm. The effectiveness of the offline adaptive method was attributed to compensating for the systematic baseline shifts. However, the daily online correction strategy was deemed to be useful for patients who exhibit large variations in the daily mean tumour position. More investigation is required into the anatomical and biological changes of lung cancer tumours to determine more complex applications of adaptive radiotherapy for lung cancer[29].

Implementation

Adaptive radiotherapy is not routine in most departments. Even at the simplest level, daily online IGRT can be resource intensive particularly if soft tissue registration is required. Radiographer rather than clinician-led verification can improve efficiency but may require additional training. Studies investigating plan of the day approaches have shown acceptable concordance (>70%) with clinician and radiographer[17]. Furthermore, when clinically implemented, concordance increased to 95% with two radiographers agreeing image registration[18]. Training was also identified as a requirement in the development of a credentialling programme for bladder cancer, in addition to the ability to plan multiplans and quality assurance of the IGRT process[30].

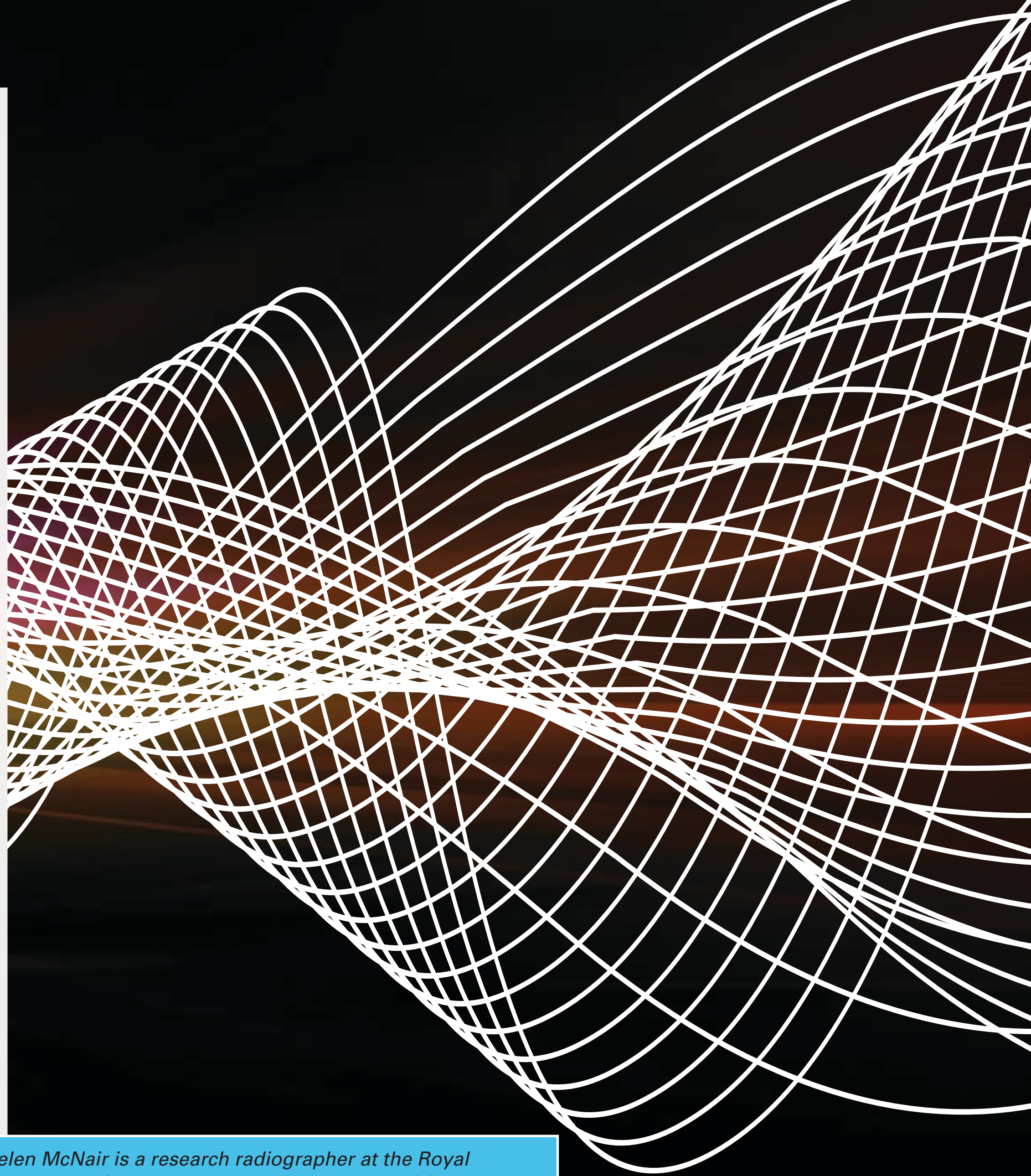
However, the tools and equipment available will influence the adaptive method of each department. For example, in studies by Schwartz et al, in-room CT allowed more efficient replanning because the CT images acquired could be used immediately for replanning without requiring an extra visit or scan for the patient[24,25]. It is not possible, with all imaging systems, to use the CT values of the CBCT for dose calculations because of the possibility of inaccurate dose calculations. There are methods developed to overcome this[31]. The CBCT dataset can be compared to the CT dataset and CT numbers assigned, depending on overlap or lack of anatomy between the two datasets[32]. Another method uses the planning CT to provide a crude correction to the CT numbers[33]. If an efficient process can be established, the burden of replanning may not be extreme. For example, in one department treating 5000 patients, approximately 1200 with CBCT scans, 254 patients (21%) were reviewed and of those, around 45 (18%) required a replan (Rowbottom C, personal communication). Investment and development of tools for accurate imaging, automated outlining and efficient dosimetry to enable replanning for adaptive radiotherapy are essential to streamline the process. This would also allow more investigation with larger groups of patients to determine thresholds and/or triggers for rescanning and replanning. Good and effective communication between the disciplines is essential to inform these decisions and requirements.

Conclusion

Adaptive radiotherapy has the potential to improve delivery of the dosimetry to the target, whilst maintaining reduced dose to the organs at risk. However, the effect on patient outcome remains to be determined. Efficient tools need to be developed to enable further investigation into the need for accurate replanning and to determine application, frequency and effectiveness on outcome.

Footnote

(1) CHHiP: Conventional or Hypofractionated High Dose Intensity Modulated Radiotherapy for Prostate Cancer (ISRCTN 97182923). IMPORT: Randomised trial testing dose escalated intensity modulated radiotherapy for women treated by breast conservation surgery and appropriate systemic therapy for early breast cancer (ISRCTN 47437448).



Helen McNair is a research radiographer at the Royal Marsden NHS Foundation Trust and Institute of Cancer Research. She completed her PhD in improvements in accuracy in radiotherapy in 2010, and she is currently chair of the BIR oncology committee.

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{28} CONTROVERSIES IN COMPRESSION FORCE

PETER HOGG, CLAIRE MERCER, ANTHONY MAXWELL, LESLIE ROBINSON, JUDITH KELLY, FRED MURPHY

For many years mammography has played a key cancer detection role in the assessment of screening and symptomatic populations. Controversy has surrounded screening[1] but new European work has re-emphasised its value[2].

A recent independent review within the UK indicated that screening does reduce breast cancer mortality, but over-diagnosis also occurs; it concluded by indicating that information for women should be more transparent and objective so that informed decisions can be taken[3]. For the moment we can assume that mammography will continue in widespread use, indeed its use is likely to increase because of the screening age extension[4] and the expectation that breast cancer incidence will increase considerably by 2040[5].

Given that mammography is well established, there is surprisingly little published empirical research into the technique of performing it. This is particularly true for the application of compression force. During the examination the breast is compressed to reduce breast thickness as this is said to have several values, including radiation dose reduction[6], enhancement of image quality[7] and lesion visibility, and minimisation of patient motion[8]. Literature exists to describe how compression force might be applied[9,10] and by what amount. Based on such literature, guidelines have been drawn up to inform practice[8]. However, most literature provides anecdotal or theoretical perspectives and few are based upon quality empirical observations. Perhaps a consequence of this is that compression force guidelines tend to be highly general and detailed information is lacking.

For the breast screening service as a whole, quality assurance is rigorous and it has been an integral part of the service since its introduction in 1988. All screening programmes have to adhere to stringent quality standards, with strict quality control procedures which are monitored by regional quality assurance reference centres[9]. Whilst such standards have rightly focused on patient outcomes, such as cancer detection rates and screening to result targets, the independent monitoring of practitioner standards is achieved through tight monitoring of programmes' technical repeat and recall rates. No direct quality standards are associated with practitioner compression force performance.

This article draws on new research, conducted in collaboration with the University of Salford, which has a particular focus on breast compression force.

Variability in compression force

In 2004 Poulos and McLean[11] published a small research study which required two practitioners to compress a woman's breast independently. Compression force differences were noted between the two practitioners for the same woman. From this, Poulos and McLean predicted that variations between practitioners could exist, however further work needed to be conducted to verify this.

Their prediction was not confirmed until 2013, when Mercer et al[12] concluded that variability between practitioners does exist. Mercer's cross sectional study, involving 500 clients and 14 practitioners, identified three types of 'compressor' – low, intermediate and high, with significant compression force differences existing between these groups. Following on from this, Mercer et al[13] reported on a six year longitudinal study, over three screening rounds. A different patient cohort was selected for this study but the practitioners remained the same. The 'compressor' trend

> "There is a subset of women who are permanently put off reattending after their first screen"

was sustained and implications for clients were determined. For the same client across the three screening rounds, considerable compression force variations existed, breast thickness differences were noted and variations in mean glandular dose also occurred. In both studies it was suggested that the amount of applied compression force was more dependent upon the practitioner than the client and this might be due to the poor quality of published evidence and the lack of detailed clinical guidelines. Not surprisingly, Mercer et al concluded by suggesting that better evidence needed generating so that guidelines can be more explicit and image quality and patient experience would be more consistent.

Client experience

Mercer's work leads us to question what the attitude of the service user (eg client) might be to practitioner compression force variability. Women find compression force uncomfortable and many studies report that a number of patients experience moderate to severe pain[14,15,16,17]. Although Myklebust et al[18] showed women tolerate pain as a necessary aspect of the examination for maximising diagnostic yield, Dibble et al[19] have shown up to 8% of women delayed or missed appointments because of the pain experienced at previous examinations. Clearly, breast compression force variability has the potential to influence women's behaviour and attitude towards mammography. Consequently, Robinson and Newton-Hughes[20] explored what practitioner variability might mean to National Health Service Breast Screening Programme (NHSBSP) service users. This study investigated how service users would interpret Mercer's practitioner variability work and whether this might influence their behaviour.

Employing a feminist research methodology, Robinson and Newton-Hughes' study comprised three focus group interviews involving 14 women. All participants indicated that Mercer's findings were interesting, although some of them were not surprised as they had experienced variation in compression force between visits themselves. One participant said she had even experienced variation in compression force between breasts during one visit. Another participant found the variability research quite alarming, suggesting it was unethical to compress the breast more than was necessary.

Despite a logical interpretation of Mercer's findings (eg that variation in practice might suggest high levels of compression force may not be necessary), only two participants said they felt empowered to change their behaviour at future mammography. The majority did not believe this new knowledge would influence their behaviour because they viewed the practitioner as the expert and to question them was inappropriate. It appears that the provision of evidence may not be sufficient on its own to change behaviour. Robinson and Newton-Hughes also showed that involving service users in evaluating research is essential, because it offers an alternate lens through which to consider the findings. Furthermore, because Robinson and Newton-Hughes employed a feminist approach, the participants were empowered to talk about what was important to them; it provided a more holistic understanding of how compression force was viewed and its relative importance in the context of mammography more generally. This way, like Poulos and Llewellyn[21], Robinson and Newton-Hughes showed that compression force related pain is not necessarily the chief concern for service users and other aspects of the screening experience could have a profound influence on discomfort.

A recent ongoing and unpublished study of breast screening reattendance rates has demonstrated that women who have been screened only once previously (and had a normal screening result) are six percentage points less likely to reattend than women who have been previously screened more than once. This suggests that there is a subset of women who are permanently put off reattending after their first screen, presumably because they view it as a painful or otherwise negative experience.

Why does practitioner variability occur?

Aside from breast composition and volume changing over time, explanations have been offered that might explain why compression force variations within women might exist, a noteworthy one being breast tenderness in relation to the menstrual cycle[22]. However, Mercer's findings cannot be explained by breast tenderness, composition or volume change as her two studies clearly point to variability being practitioner-focused. Consequently, a national qualitative project to investigate the compression force behaviours of practitioners, and how they were taught to apply compression force, was conducted[23]. This project investigated compression force behaviours and explored individual and collective beliefs and values that influence compression force practice. Ultimately, it sought to identify the 'why' and 'how' of breast compression force. Concurring with Mercer, early findings showed variability on both how and why compression force is applied.

Many practitioners never referred to the numerical value of compression force being applied, but made a decision on the look and feel of the breast. In contrast, others used the compression force level as a final check rather than a primary assessment before making an exposure. The speed with which the compression force was applied also varied. Some mammographers tended to use the (fast) foot control until the final part of the process and then preferred the (slow) manual hand control. It was felt they could apply additional force whilst being sensitive to the patients' discomfort if this approach was adopted. Another method involved client empowerment; here control was given to the client for the final level of compression force. However, this was not always the case and some admitted to using white lies in order to attain that final level. It was recognised that clients would often compare their experience with a previous examination (if they had one) and staff were very mindful of this fact. Practitioners were concerned that a poor experience may result in a subsequent non-attendance.

Practitioners felt that for those clients attending for the first time, expectations were quite diverse but generally never as bad as they had anticipated. When speaking about compression force, practitioners demonstrated a good deal of self-doubt about their practice, and with no evidence of peer observations. They indicated it was impossible for them to know if they were performing mammography in the same manner as their colleagues. Values and beliefs specific to each centre were also evident, adding to the variability of the mammographic experience.

Towards minimising variability

Existing literature

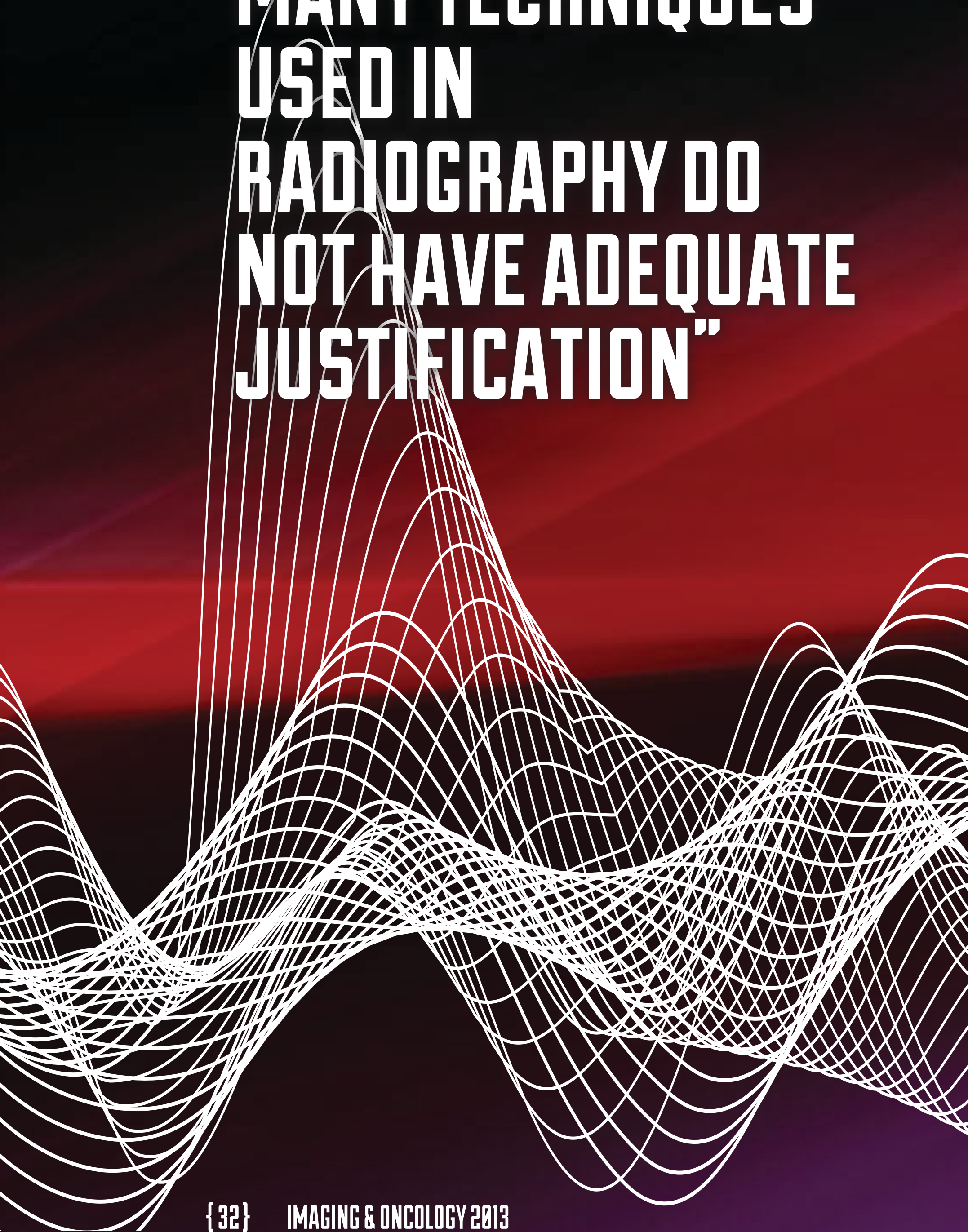
Various compression force guidelines and publications exist to help guide practitioners. For instance the NHSBSP indicates that the compression force should be applied slowly and gently to ensure the breast is held firmly in position and that 20kg (20daN) of force should not be exceeded. Generally speaking, these publications offer descriptive accounts with limited or no evidence-base and, not surprisingly, translating them into practice is likely to give rise to variations. However, they do provide a base upon which to build.

Clinical image quality

Routine quality control tests are conducted on mammography equipment to ensure dose is consistent and adequately controlled and that mechanical safety is assured[9]. Ultimately these tests ensure that imaging and display equipment is fit for purpose. Beyond this the assessment of (visual) clinical image quality is the key indicator to determine the success of the mammogram. Clinical image quality should be considered in two ways – visibility of lesions and overall quality of the image. FROC (free-response receiver operating characteristic) analysis[24] would assist for the former and some form of visual grading would be ideal for the latter. Two visual grading scales have gained widespread application.

"A robust consistent routine method for evaluating overall clinical image quality does not exist"

> **"Many techniques used in radiography do not have adequate justification"**



PGMI[25] categorises mammography images as (P) perfect, (G) good, (M) moderate and (I) inadequate; the second scale[26] evaluates images on the basis of exposure, contrast and sharpness. This second scale is used when evaluating images for the introduction of new equipment into the NHSBSP. Surprisingly neither of these scales has been validated – which brings into question the confidence with which they can be used. One scale has reached a level of development such that some validation data have been published[27], but this scale is not used in practice. The lack of published evidence about image quality scale performance severely confounds visual grading for research purposes. For clinical purposes mammograms tend to be reviewed for quality, based on simple checklists or by using one of the two scales that have gained popular use. A robust, consistent, routine method for evaluating overall clinical image quality does not exist.

The relationship between compression force, breast thickness and clinical image quality

If the relationship between compression force and clinical image quality/ lesion visibility is true then it is important to understand how in-vivo breast thickness varies with increasing amounts of compression force so that a more informed decision can be taken about its application. Until recently no robust information has been published about this.

In 2013[28] Hogg et al published a study to describe the relationship between breast thickness and compression force. Knowing that data from different mammography units cannot be combined because of variability errors,[29] this research drew data from one machine (235 women; 940 compression force sets) for craniocaudal (CC) and mediolateral oblique (MLO) projections. Breast thickness/compression force change graphs were derived and the data demonstrated a good fit to polynomial equations. Differentiating the curves for gradients, critical junctures were determined at which the rate of change of pressure/thickness occurred. Through extrapolation the maximum amount of compression force which (theoretically) could be applied was identified. Interestingly, although this fell within the NHSBSP maximum compression force parameter, it was below the maximum. The point at which little thickness reduction was achieved for further increasing pressure was also identified, as illustrated in figure 1.

The graph is divided into zones: rapid rate of change (light grey) – here small amounts of compression force give rise to large thickness reductions; medium rate of change (mid grey) – here the rate of change is slower, indicating that more compression force is required for thickness reduction; and finally, slow rate of change (dark grey). The practitioner should aim to enter the mid grey zone, but not progress into the dark grey zone because little thickness reduction is achieved within that zone. Hogg et al[28] propose that the graphs could be used to help guide compression force practice on first presentation. For subsequent presentations the practitioner would consider the graphs, along with the recorded compression force values from the previous visit.

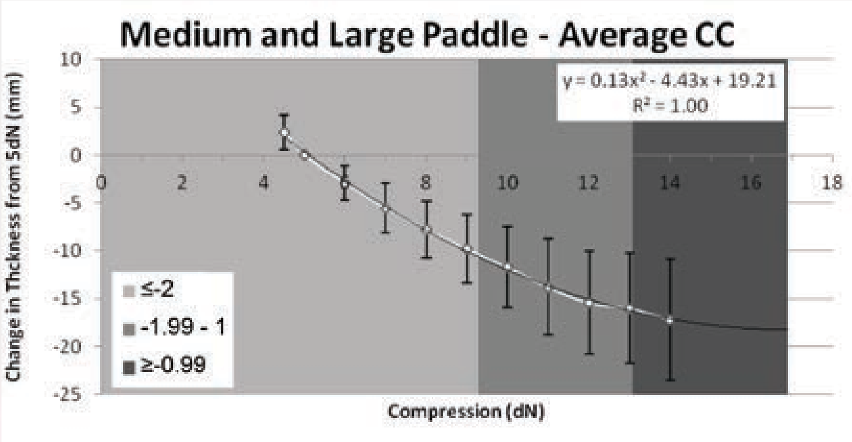


Figure 1: Craniocaudal projection.

Relative position of inframammary fold and image receptor

Many techniques used in radiography do not have adequate justification and determining best practice can be difficult because of lack of quality evidence, notably empirical research. A clear example of this concerns how the image receptor (IR) might be positioned relative to the inframammary fold (IMF). Some literature supports breast elevation in relation to the IMF in order to perform the CC projection[30]. Theory indicates that IMF elevation would bring the object (lesion and breast) closer to the IR, and this should enhance image quality. Coincidentally, elevating the breast relative to the IMF might also balance the pressure exerted from the paddle and receptor onto the breast and improve the patient experience. Until recently, no empirical data within the literature affirms or refutes elevation of the breast relative to the IMF. Nevertheless, despite the lack of evidence, a variety of different breast positioning techniques have been taught for many years.

Using a breast phantom and pressure mapping system, work recently reported by Hogg et al[31] provided the first evidence to show that the amount of breast in contact with the IR is likely to increase as the receptor is elevated. Similarly the pressure from paddle and receptor onto the breast becomes better balanced when the receptor is elevated. Figure 2 demonstrates how 'pressure balancing and area on IR' (Uniformity Index) vary with relative IR and IMF positions. Hogg et al propose an elevation of 1-2cm in order to give the best pressure balance along with the largest amount of breast in contact with the receptor. However, caution should be exercised with this work because it is phantom-based, although work on women participants using the same method has recently been completed[32]. Here 16 female volunteers each received two compressions to each breast. The CC was positioned with IR at IMF, then 2cm above the IMF. Initial analysis indicates that in all cases raising the IR 1-2cm vertically relative to the IMF increases the area of breast in contact with the IR.

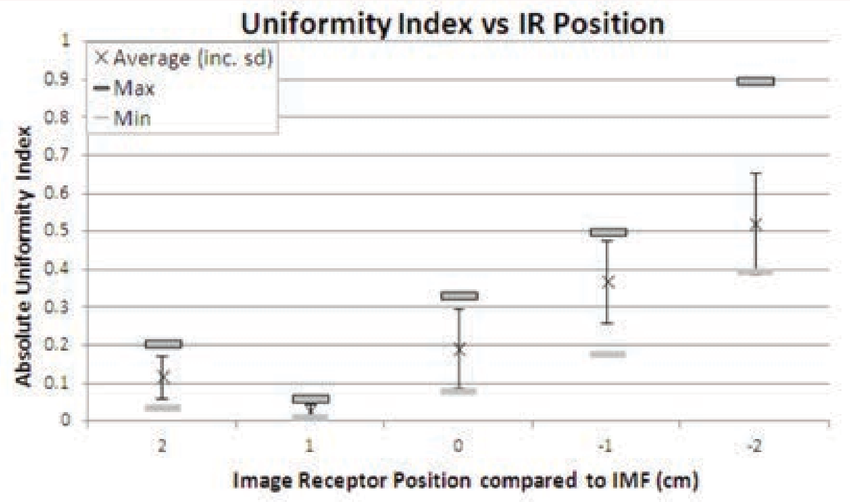


Figure 2: Uniformity Index: pressure balancing versus area on IR.

Conclusion

Research has shown that compression force variability can exist between practitioners. On reflection it is apparent that this problem is likely to occur because there is almost no empirical evidence upon which to base compression force practice. This is quite surprising because mammography is a highly common procedure conducted on a large number of women per year through screening programmes or the investigation of symptoms.

Reflecting on the current state of evidence provided to assist practitioners in their endeavour to perform mammography to an acceptable and consistent level of practice, we suggest that considerably more research is required into the fundamentals of the technique.

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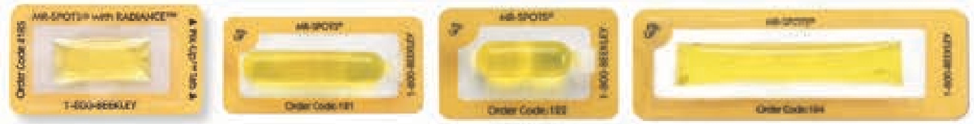

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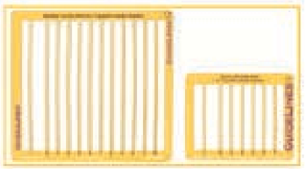

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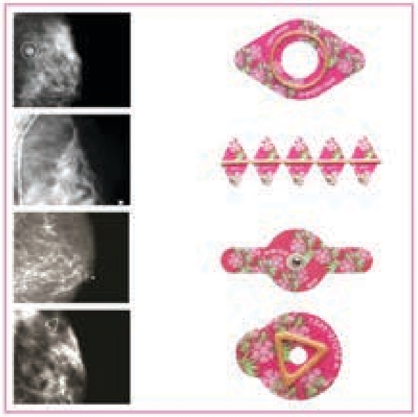

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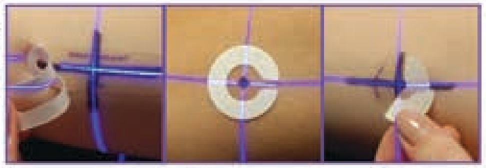

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RADIOGRAPHY AND RESEARCH: A CHANGING CULTURE

HEIDI PROBST, HELEN L GALLAGHER

Evidence-based practice is an essential requirement of all healthcare professionals. Indeed, one of the defining qualities of any profession is to contribute to the body of evidence that underpins its practice and enables it to develop and advance. Thus it is disappointing to observe that in a recent report[1] radiographers, despite being the third largest of the allied health professional (AHP) groups in the UK, are still perceived to be the poor relations when compared to other AHPs, in terms of overall research capacity and research output.

As far back as 2001, Nixon raised awareness of the potential threat to the 'professional status' of radiography indicating that 'much of its knowledge base was built on research undertaken by medical practitioners and physicists, rather than by radiographers'[2]. If, as has been advocated many times in recent years, the 'development of a strong research culture is a necessity for the continued development of the radiographic profession'[3], then it is clear that radiographers need to 'up their research game' in both quality and quantity. This is not just to gain recognition from our healthcare colleagues but, more importantly, to ensure optimum patient care and management, underpinned by the most robust and reliable evidence. This paper reflects on the early beginnings of research radiography, explores where we are now, looks to where we want to be in the future and considers how we may get there.

In the beginning

For the last two decades the profession of radiography has been established as graduate entry. The move away from the diploma, with its didactic and rigidly knowledge-based teaching, to first the degree and now the honours degree, has enabled a new generation of radiographers, equipped with attributes befitting a professional, such as skills in critical thinking and leadership, lifelong learning and continuous development. The new curricula promote greater autonomy, accountability and clinical decision-making and thus it was the 'establishment of the graduate radiography programmes that brought a shift in the educational focus from knowledge-based to evidence-based'[4]. Prior to this, radiography was based on established practice and the instructions of medics and physicists. The traditional remit of a 'research radiographer' was to collect data for the research of others; a predominantly protocol driven, though nonetheless essential, activity to which radiographers are accustomed. For this contribution they only occasionally received acknowledgement and rarely achieved an authorship. Furthermore, much of the research being undertaken was not necessarily aimed at advancing the profession, practices or evidence-base of radiography. For this to occur, radiographers had to identify gaps in the knowledge-base and develop, implement and essentially lead research studies to address these. Yet radiographers have largely displayed a reluctance toward engaging in, and more importantly, leading research. The main reasons for this appear to be linked to research capability, capacity, and funding opportunities[4,5,6,7,8].

Firstly, studies have reported that radiographers lack confidence to lead research[4,7,8]. Research methods teaching is now embedded in all undergraduate programmes, providing an introduction to research design and implementation[9]. The focus on research methods training at this level is to enable student radiographers to access and critique the evidence in order to make informed choices that influence policies and patient management, but also to provide an insight and hopefully a motivation to develop research skills throughout their career. Research projects undertaken as part of a first degree are unlikely to contribute significantly to the body of evidence underpinning our practice, as they are subject to a number of constraints that limit the time available to collect data for a satisfactory sample, including submission deadlines and ethical approval procedures. Masters level training builds upon the research knowledge skills, but has similar limitations and does not necessarily foster the attributes required to promote autonomous research practice and leadership. Lee et al[10] have identified that there is a need for training in research leadership in both the clinical and academic environment for radiographers to drive forward the research agenda of the profession. To achieve the competence and confidence to direct research and convince funding bodies and collaborators of research credibility requires more focused training to doctoral level. However the lack of defined career pathways presents another perceived obstacle, as such training requires considerable commitment and often personal sacrifice, with little or no incentive from a professional progression stance. Time to undertake effectively high quality research, exacerbated by staff shortages are two other commonly cited obstacles. However, these are all challenges that can be directed at any of the allied health professional groups to a greater or lesser extent.

A particular challenge to radiography research is resourcing. The highly technical nature of radiography and radiotherapy means that much of the research directly underpinning practice is expensive, even at a proof of concept level. Unfortunately funding bodies often require pilot data and demonstration of a robust research track record before committing more significant funds. This 'chicken and egg' dilemma makes it difficult for novice researchers to even dip their toe into the research pool. It is little wonder that radiographers are perceived to have a poor attitude towards research.

Where are we now?

Since the study by Challen et al[5] the research culture in radiography has begun to evolve and positive efforts have been made to overcome some of the obstacles described above. A number of studies have sought to identify the skills and attributes required to equip radiographers for effective research and evidence-based practice[4,7,8,11] and in doing so have revealed a positive shift in attitudes towards research and research utilisation. A survey of 218 UK based sonographers[7] reported that the majority of their sample held a positive attitude to research and recognised the benefits of research to their own departments. Encouragingly, more than half of their sample did not see the need for research to be led by medics or that their research involvement should just be in following protocols for other professional groups to lead on the intellectual input. Most

"THE TRADITIONAL REMIT OF A 'RESEARCH RADIOGRAPHER' WAS TO COLLECT DATA FOR THE RESEARCH OF OTHERS"

sonographers hold a postgraduate qualification and enjoy more autonomy than many radiographers in traditional radiography practice, therefore it could be argued that the population sampled here cannot be generalised to radiographers as a whole, but nonetheless suggests a more proactive and empowered attitude towards research activity.

The perception of the role of the research radiographer is also evolving[12] and clear career pathways have been identified through the introduction of National Researcher Profiles ranging from Clinical Researcher (band 6) to Clinical Researcher Consultant (band 8b-c-d). Other professional disciplines are promoting multidisciplinary research and collaboration with higher education institutes (HEI) to support the development of research protocols and provide gravitas for grant applications. The research capacity of radiography academics is rapidly increasing. A brief survey sampling just 11 out of a possible 25 HEIs in the UK conducted in January 2013 by the authors demonstrated that approximately 13% of academic radiographers currently hold a doctoral level qualification, with a further 26 working towards this, which means that this figure is set to increase to 31% in the next three to five years. This is a considerable improvement from 2006-7 in which only 6% of academic radiographers were reported to hold a doctorate[13].

The vision of the Society and College of Radiographers (SCoR) is to 'foster professional growth and improve the standards of delivery and practice of radiographers, by promoting leadership and by expanding a body of knowledge through education and research'[3]. It aims to encourage all radiographers to use research evidence; to assist those radiographers who wish to undertake research, by promoting the use of current best evidence-based practice and investigating knowledge gaps; and to excel in the provision of best patient care by supporting radiographers to appraise evidence and implement best practice.

To fully achieve the aspirations of the SCoR research vision requires a culture shift in radiography; a recognition of the collective responsibility of all radiographers to access, contribute to, disseminate and implement the evidence-base underpinning our practice in order to primarily achieve the best patient care and management but also to maintain our professional credibility.

Our time is now

Looking to the future as a profession, where are we headed? How do we get there? And do we have any kind of plan?

Where are we headed?

We have already identified that central to professional practice is the need to add to the evidence-base. Indeed at the heart of the radiography profession is our code of conduct[14] where the scope of practice identifies:

"You must seek to further the profession of radiography…"
"You should either conduct research or be involved in research or its dissemination in order to further the evidence-base of the profession"

It is evident that we all have a responsibility to support research (either through conducting or using research evidence in our practice) to further our profession. It is at the heart of our code of professional practice, so our goal must be to seek to increase radiographer led research activity to further our profession.

In addition, the Department of Health QIPP (quality, innovation, productivity and prevention)[15] agenda requires practitioners to consider efficient and productive ways of providing safe care for patients. This agenda needs innovative practitioners with research skills to drive change. Furthermore, Health Education England's new Education Outcomes Framework consists of five domains; domain three is specifically related to the development of a flexible adaptable workforce responsive to innovation with knowledge of research[16]. The message is clear; research is fundamental to the development and enhancement of services.

How do we get there?

There are over 130,000 AHPs working across a range of sectors in the UK, contributing critical expertise in a number of care pathways[17]. However, research from AHPs is known to lag behind nursing, medicine and clinical scientists, resulting in a substantially lower evidence-base to services and care compared with other professions. As a profession, we may be even less research active than other AHP colleagues. As already identified, the number of radiographers trained to PhD level as a proportion of the total size of the radiography profession is low compared with other health professions such as nursing and other AHPs. For example, in 2004 there were around 200 physiotherapists with PhDs. Almost ten years later, in 2013, there are less than ten therapeutic radiographers with PhDs; we have some catching up to do.

Research is inextricably linked to innovation and service development. The development and testing of novel treatments or interventions from radiographers will be restricted while a gap exists in radiographer research activity. Commentators have recommended the need for investment in research training of AHPs, not just at doctoral level but at all levels[18]. Furthermore, a gap analysis of research radiographers working in radiotherapy (n=70) identified shortfalls in research training received[19]. Over 50% had not received any training in grant writing, over 40% reported no training in the clinical trials directive, and more than 25% had not received any training in statistical analysis or scientific report writing. Discussion with research radiographers through national forums suggests this situation has not changed over the five years since this survey. This demonstrates that even practitioners working within the research environment (in research roles) may lack the relevant skills to lead research activity and hence innovation in service delivery.

There are a number of validated research programmes that radiographers can access across a range of HEIs. Although many busy radiographers do not have time, funding, or the desire to access and complete formal university credited research programmes, feedback from national research workshops for radiographers supported by the authors indicates a desire from practitioners to improve their research skills; however, this needs to be delivered in a flexible way that suits practitioners' working patterns and personal commitments. Research shows formal education increases the confidence of those moving into specialist roles[20] and hence formal education in research delivered in a flexible way should increase the opportunity for greater radiographer research and innovative activity.

Do we have a plan?

The College of Radiographers' research strategy paper[3] is not just a vision document but has a number of schemes designed to improve the research capacity and capability of the profession. These include collaboration with industry partners to provide funding specifically for radiographers at the early research career stage. Successful applicants from this scheme then have credible research experience that will enhance future applications to larger national and international funding bodies such as the research councils and the National Institute for Health Research. The College of Radiographers Industrial Partners (CoRIPs) research funding has been running for a number of years and we are now starting to see the benefits of novice researchers that have been supported under the scheme moving on to PhD study and developing post doctoral research portfolios.

Other facets of the CoR research strategy include a commitment to support research networks and hubs. The CoR research group is currently investigating the development of a virtual research hub to enhance the opportunity for collaborative research, networking and knowledge transfer. In order to establish progress in implementing the aims of the CoR research strategy we need to measure current research activity and capacity. An immediate objective of the CoR research group is to audit current research capacity within the profession. The survey will be sent to managers and research leads to help us quantify the number and range of research posts, the links and research networks that radiographers are involved in, facilitators and barriers to research, publication and dissemination activities and the current infrastructure in place in imaging and radiotherapy departments to support research activity. The survey will initially be sent to radiotherapy departments, followed by a survey of imaging centres.

Conclusion

Evidence-based radiography is critical to providing safe and effective patient care. Research influences policy and practice, enables the appropriate allocation of resources, provides us with the necessary intelligence to strategically plan for future healthcare needs and is essential to maintaining the status of radiography as a profession. Thus, we all need to embrace the research agenda. It is at the heart of developing and enhancing services. We currently lag behind other professions in terms of the amount of research conducted to provide an evidence-base to our practice. We have substantially less radiographers with PhDs than other AHP professions, although there is encouraging evidence that doctoral training within the profession is on the increase.

As a profession, we need to ensure radiographers have the relevant skills to apply for funding, conduct high quality research and disseminate their findings to suitable audiences. Practitioners applying for, or within, research roles need to ensure they develop the relevant skills to ensure the research they undertake is of high quality and likely to have impact on care of the patient or service delivery. Education and training in research methods must be flexible to meet the needs of busy professionals. HEIs should consider accessible ways of matching the delivery of research methods courses with the restrictions that come from a need to ensure departments maintain staffing levels.

Auditing current research activity and capacity is essential if we are to measure progress towards our vision and identify areas where we need to focus activity. The CoR research strategy provides a framework for developing research capacity within the profession, but we all need to sign up to it.

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{ 42 } STATE-OF-THE-ART NUCLEAR CARDIAC IMAGING: CARDIAC PET – CURRENT STATUS IN THE UK AND FUTURE DIRECTIONS

RANDEEP K KULSHRESTHA, PARTHIBAN ARUMUGAM

Coronary artery disease (CAD) remains a major health concern within the UK causing approximately 80,000 deaths per year[1]. Early diagnosis and appropriate management is important to reduce mortality and morbidity secondary to CAD.

There are several non invasive diagnostic modalities to detect CAD, including exercise testing, stress echocardiography, and perfusion MR (magnetic resonance). In addition, radionuclide myocardial perfusion imaging, including single photon emission tomography (SPECT) or positron emission tomography (PET) is very useful. SPECT is well established worldwide with a wealth of diagnostic and prognostic data on patients with and without CAD. PET is emerging as a genuine and worthy alternative to SPECT, especially since the increased availability of a generator-produced radionuclide, 82-Rubidium (82Rb). Although cardiac PET is rapidly growing worldwide, especially in the USA, there are relatively few centres in the UK currently performing cardiac PET.

Cardiac PET has been shown to have equivalent or better diagnostic accuracy when compared to Cardiac SPECT and Cardiac MR[2]. There are also emerging data on the prognostic value related to PET perfusion imaging[3].

The focus of PET-CT scanning has been oncology within the UK, with funding from the National Cancer Network, and less on cardiac imaging and hence funding for this technique in these difficult economic times has been a major challenge, further limiting its potential, more widespread availability. Now there is increased interest in its applications for cardiac disease.

A recent document produced by the Royal College of Physicians and Royal College of Radiologists Nuclear Medicine Working Party[4] regarding evidence-based indications for the use of PET-CT in the UK has acknowledged that both 13N-Ammonia and 82Rb are useful and superior to Technetium labelled SPECT agents for the assessment of myocardial perfusion. In addition, metabolic imaging with 18F-FDG (18F-fluorodeoxyglucose) is considered to be useful in the assessment of myocardial viability in patients with ischaemia-induced heart failure.

The more widespread availability of PET-CT scanners in the UK, along with the availability of generator-produced 82Rb has made cardiac PET imaging feasible.

General principles

Cardiac PET requires the intravenous administration of a radioactive radionuclide on its own or tagged to a pharmaceutical which targets the heart. PET tracers are produced either in a regional cyclotron (ie particle accelerator used to produce short lived positron emitting isotopes) or locally in a generator[5]. 82Rb is generator produced and 15O-Water and 13N-Ammonia are cyclotron produced cardiac PET tracers.

Depending on the myocardial extraction of the tracer, tracer delivery is proportional to cardiac blood flow. The most physiological tracer is 15O-Water, with tracer delivery being directly proportional to flow, but it is not possible to obtain clinical images practically, due to very quick equilibration between vascular and tissue compartments[6,7,8]. 13N-Ammonia, in turn, has a better extraction fraction than 82Rb and is more linear to the blood flow[9]. Due to practical advantages, which will be outlined later, 82Rb is however, the most widely used myocardial PET tracer.

After injection, the PET tracer is taken up in the heart. Radioactive decay then occurs within the heart, whereupon a positron or positively charged

> "Having both PET and CT information avoids unnecessary invasive coronary artery catheterisations"

particle moves approximately 1mm and then collides with an electron or negatively charged particle in a process known as 'annihilation'. As a result, high-energy gamma photons are produced, move in opposite directions to each other and subsequently get detected by the PET scanner.

Although the photons have higher energy than conventional SPECT using Technetium (511 keV versus 140 keV), the photons traverse the whole length of the body, which increases the likelihood of both soft tissue 'deflection' or attenuation and photon scatter[10]. CT derived soft tissue attenuation correction is very accurate, as is mathematical modelling for scatter correction to reduce this 'deflection' error, which makes it possible to accurately quantify tracer distribution within the myocardium. The ability to perform accurate soft tissue attenuation correction and scatter correction also makes it possible to non-invasively quantify myocardial blood flow in ml/gm/min with cardiac PET.

The main advantages of Cardiac PET compared to SPECT are outlined in figure 1[11,12,13,14]. This article focuses on 82Rb for myocardial perfusion and 18F-FDG PET radiotracer for myocardial metabolism.

Figure 1: The main features of Cardiac PET and SPECT.

SPECT ADVANTAGES	SPECT DISADVANTAGES	Why perfusion PET?
Excellent prognostic value	Two day visit or longer stay per visit	Single patient visit
Widely available and cheaper	Radiation dose higher to patients and staff	Reduced radiation dose to patient and staff
Recent developments in hardware and software	Attenuation and scatter correction not 'ideal'	Better attenuation and scatter correction
	Relative perfusion assessment	Absolute blood flow measurement
		Better specificity
		Better sensitivity
		Emerging prognostic value

Myocardial PET perfusion tracers

82Rb is produced from a Strontium-82 (82Sr)/82Rb generator (figures 2a and b), which can be eluted every 10 minutes. 82Sr decays to 82Rb by the process of electron capture. This has a lower radiation exposure (approximately 3 mSv) compared to conventional SPECT (range 7-15 mSv) due to its shorter half life (75 seconds). It is thought to be more practical

"There is potential for important cost savings"

Figures 2a and 2b. Strontium/Rubidium Generator (2a above left) CardioGen-82 Bracco Diagnostics). Rubidium-82 eluted from strontium-82, before being administered into patient via a saline infusion (2b above right). The white cabinet houses the Rubidium-82 Generator, a pump, control electronics and connecting tubing. Quality control of the amount of radioactivity present has to be done on a daily basis. The generator can be fully replenished every 10 minutes, allowing for rapid completion of rest and stress studies.

clinically to use with this generator system compared to cyclotron-produced compounds[15].

The half-life of the parent radionuclide 82Sr is 25.5 days, which results in a generator life of four weeks. The short half-life of 82Rb (ie 1.25 minutes) allows repeated and sequential perfusion studies but does require rapid image acquisition shortly after tracer administration.

13N-Ammonia is a cyclotron produced perfusion tracer. It has better tracer kinetics (more linear relationship to blood flow) than 82Rb and better image resolution, but an on-site cyclotron is necessary due to its shorter half-life (10 minutes), hence significantly restricting its current use in the UK[16].

Myocardial imaging protocols

Patient preparation

The patient should abstain from caffeine-containing products for at least 12 hours and also avoid Theophylline containing medications for 48 hours prior to the test. They are allowed to have a light meal a few hours before their appointment.

Stress testing protocols

Cardiac PET stress testing is usually performed pharmacologically with either adenosine or dipyridamole. These agents cause coronary vasodilatation by adenosine interacting with the adenosine A2A receptors in the cell membrane. More selective A2A-receptor agonists are now available (Regadenoson)[17] with faster stressing procedures and fewer adverse side effects. Exercise stress is a valid alternative but can be technically demanding with 82Rb and is performed only in the research setting, however exercise is feasible with 13N-Ammonia[18].

MPI PET-CT camera protocols

A CT scout scan is performed initially to ensure that the patient is adequately positioned. A CT transmission scan is then carried out for attenuation correction (correcting for differences in the attenuation properties of the soft tissues in the anterior chest wall surrounding the heart, which can alter image quality). An emission scan is then acquired at rest and at peak stress. ECG-gated acquisition allows assessment of left ventricular ejection fraction and volumes. Imaging acquisition begins as soon as the tracer is delivered to the patient from the generator. The scan duration is approximately seven minutes each for stress and rest. The protocol that we use in our institute is outlined in figure 3.

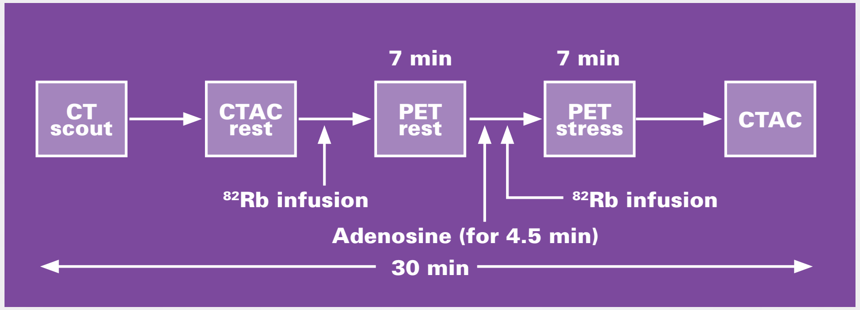
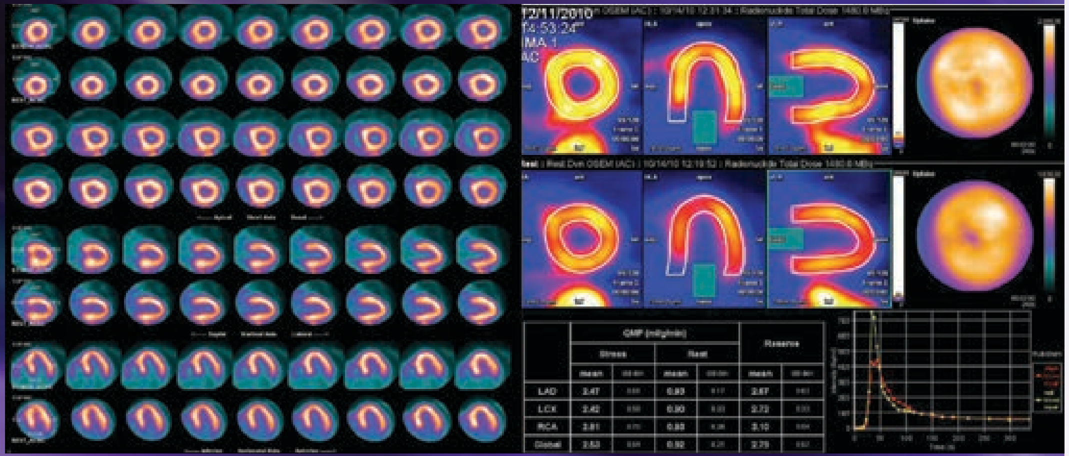


Figure 3: PET-CT protocol used at our institute using 82Rb at both rest and then stress with adenosine.

In some instances, calcium scoring is performed, which utilises the CT scan to evaluate the total coronary calcium burden. This does have a key role in helping with cardiac risk stratification, especially in intermediate risk patients, however this is undergoing further studies to evaluate its full potential, and so is not routinely performed for every patient[19,20].

Quality control

The patient has to lie on the scanning couch for 25-30 minutes. During the rest and stress scans, the patient has to be very still, as movement during PET image acquisition cannot be corrected. Reviewing the dynamic images can help detect patient motion and if there is motion detected in one or two frames, they can be omitted in the reconstruction. Patient motion between CT and PET acquisition results in misalignment for which software is available to perform manual correction.[21]



Figures 4a and 4b: Images showing normal 'relative' perfusion (figure4a above left) and normal myocardial blood flow (MBF) reserve (figure 4b above right). Expected normal range for resting MBF is 0.6 – 1.2 mg/ml/min and at peak vasodilation, the flow should increase by a factor of 2[18].

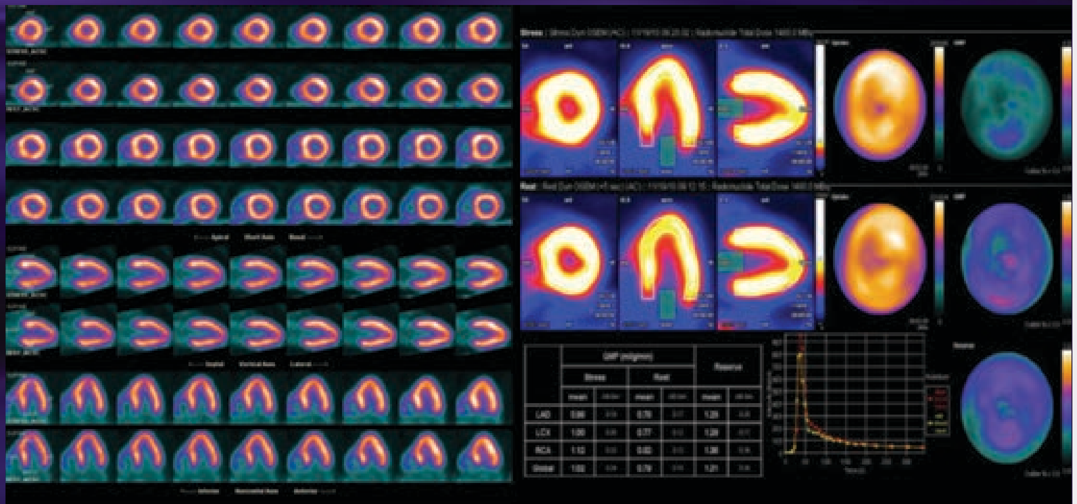


Figure 5a (above left) and 5b (above right): Images showing normal 'relative' perfusion but globally reduced MBF consistent with balanced ischaemia in a patient with confirmed three vessel disease on coronary angiography.

Perfusion ('relative') images interpretation

It is important to have a standardised method of reporting and include the number, severity and location of the perfusion defects, post stress and rest, and also mention the potential distribution of the coronary artery territory[22].

Myocardial SPECT and PET images are displayed with a schematic nonlinear colour scale of uptake (0 to 100%). The segments are normalised to the segments with the highest uptake within the myocardium (not necessarily normal) and are displayed as 100%; the rest are scaled down in relation to the tracer uptake. This way of normalising is called 'relative' perfusion assessment as it is not an absolute assessment of myocardial uptake and hence perfusion. The method has a pitfall, as segments with equally reduced uptake will appear 'normal' in cases of balanced three-vessel ischaemia. Segments that show improved uptake at rest relative to stress are reported as ischaemic and those with fixed reduction during stress and rest may represent scar tissue.

An example of normal PET-CT imaging is given in figures 4a and b, showing both the perfusion images and myocardial blood flow (MBF).

Absolute myocardial blood flow quantification

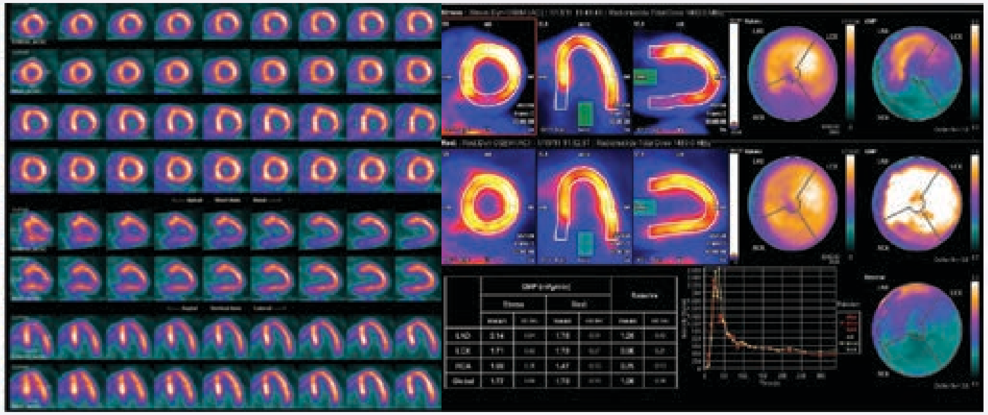
Cardiac PET imaging provides a relatively straightforward and non-invasive means of measuring MBF. PET can overcome limitations imposed by SPECT (relative perfusion assessment only) by providing superior resolution, accurate attenuation, scatter and partial volume corrections, hence allowing for accurate measurement of tracer uptake and hence absolute myocardial regional blood flow in ml/min/g. Various complex mathematical models can be used to measure absolute flow, using most commonly a single compartment model and specifically net retention models with extraction correction for 82Rb.

There are three commercial packages available for routine clinical application of MBF quantification, with either 82Rb or 13N-Ammonia. Although coronary CT and cardiac perfusion MR techniques can quantify MBF, they are not yet validated for clinical use and PET remains the gold standard for MBF assessment. There are emerging data on both the diagnostic and prognostic value of MBF over and above perfusion images.

It is likely to be helpful in the following clinical situations: balanced three vessel disease; patients with indeterminate coronary stenosis; patients with inconclusive SPECT or other functional test; possibly in heart failure, to distinguish between ischaemic and non ischaemic LV dysfunction. There are several areas of research potential, including the early detection of microvascular dysfunction, (which helps in the early detection of CAD) and the assessment of vascular dysfunction in cardiomyopathies[23,24,25].

Figures 5a and b (opposite page) show globally reduced perfusion in the left ventricular myocardium unmasked more easily with globally reduced MBF reserve.

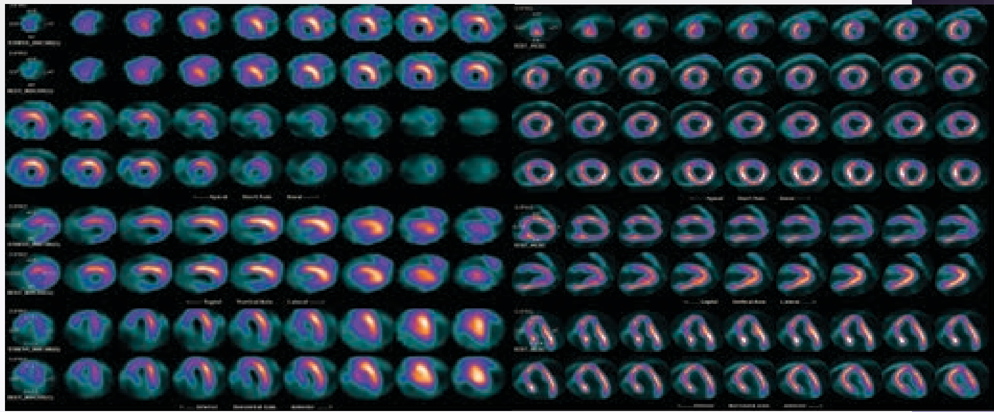
Figure 6a shows significant reversibility and ischaemia in the right coronary artery territory involving the inferior and lateral walls, however, the MBF as shown in figure 6b is globally reduced therefore also implying multivessel disease.



Figures 6a (above left) and 6b (above right): Images showing significant ischaemia in the RCA territory on the relative perfusion assessment. However there is globally reduced MBF in all three vascular territories, unmasking multivessel ischaemia.

Viability and perfusion

In patients with poor LV function, it is important to determine whether this is secondary to ischaemia, scar tissue or non-ischaemic causes. In cases of chronic ischaemia, the myocardium enters a state of hibernation, which is difficult to distinguish from scar tissue by perfusion imaging alone as both of these show reduced resting tracer uptake. Hibernating myocardium will retain metabolic activity, whereas scar tissue does not. 18F-FDG imaging is used to detect metabolic activity. Matching of normal myocardial perfusion with normal regional FDG uptake is considered a marker of normal viable myocardium. A decrease in both perfusion and metabolism is indicative of irreversible tissue injury (ie scar tissue). A mismatch between perfusion and metabolism identifies viable (ie normal FDG scan) but hibernating (abnormal perfusion) myocardium. The latter patient would more likely benefit from revascularisation. An example of this is shown in figures 7a and 7b[26].



Figures 7a (above left) and 7b (above right): Image 7a shows severe reduction perfusion to the septum and inferior wall in a SPECT study. Image 7b shows metabolic activity in the septum and most of the inferior wall, suggesting hibernating/viable myocardium on an FDG PET study.

Hybrid PET-CT and SPECT-CT scanning

There is increasing evidence documenting the value of a hybrid imaging approach, either using high-end PET-CT or SPECT-CT machines[27,28,29]. The diagnosis of coronary artery disease requires, ideally, a combination of state-of-the-art functional and anatomical imaging of the coronary arteries. A hybrid PET-CT scanner combines the benefits of a PET scanner for functional imaging of perfusion and metabolism as described and high end spiral CT scanning for anatomical CT angiography. It should however be noted that this can done in one of two ways including stand-alone hybrid machines or separate PET and CT or SPECT and CT machines with side-by-side or software fusion. The latter method does make more economic sense in most departments, but does involve two separate patient visits.

Namdar et al[30] using 13N-Ammonia in 2005 were the first to document the clinical robustness of PET-CT hybrid imaging using a four slice spiral CT scanner and showed a sensitivity, specificity, PPV and NPV of 90%, 98%, 82% and 99% respectively. Further studies using both SPECT-CT and PET-CT (with minimum 64 slice CT) have supported this early study[31,32,33].

Having both PET and CT information avoids unnecessary invasive coronary artery catheterisations, which expose patients to increased morbidity and mortality; also there is potential for important cost savings. The extra information obtained from the hybrid system over other methods could help create a unique ‘one-stop shop’ for patients, obviating the need to make multiple visits to the hospital for different tests[34].

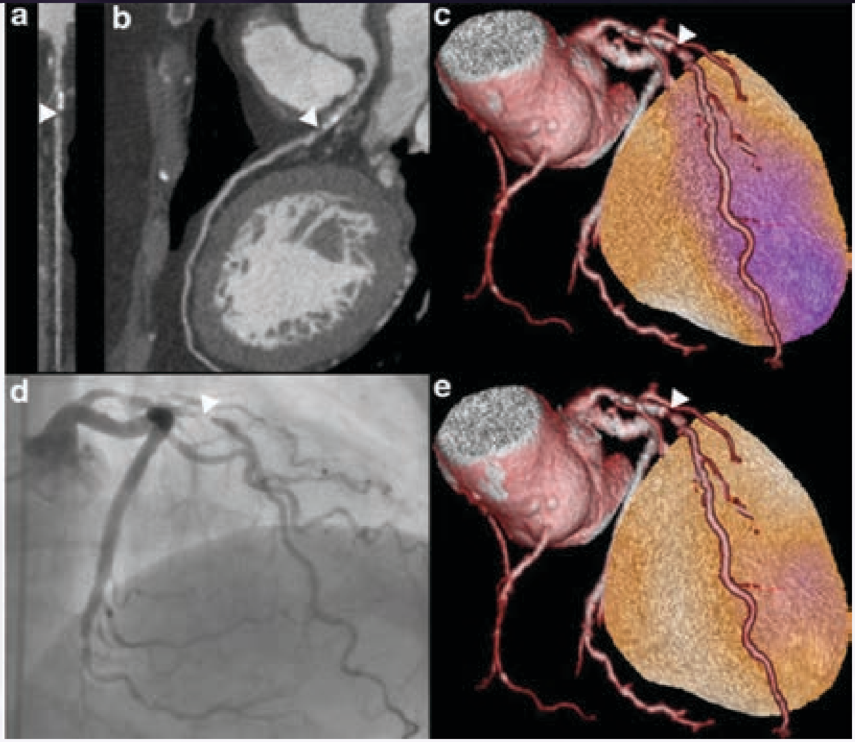


Figure 8: Cardiac image and angiographic findings. Coronary artery stenosis (white arrowhead) in the proximal left anterior descending artery is shown in the coronary CT angiography (a multiplanar and b curved multiplanar reconstruction), cardiac hybrid imaging with normal perfusion at rest (orange) and perfusion defect (pink/purple area) at stress (c), matching the territory of the coronary artery with stenosis (white arrowhead), and invasive coronary angiography (d) confirming coronary artery stenosis (Reproduced with permission from Professor P Kaufmann, University Hospital, Zurich).

An example of a hybrid or 'fused' SPECT-CT image is shown in figure 8. Similar images can also be achieved by hybrid PET-CT imaging.

The future and challenges

The development of novel newer 18-F tracers such as cyclotron generated 18-F BMS with a longer half life, can partly overcome the problems associated with costs and 82Rb. It also has a high first pass extraction rate of 94%, and is easier to distribute due to its longer half-life of 110 minutes, which allows it to be used for treadmill exercise, as well as pharmacological stress. This is currently undergoing clinical trials, but it is likely in the future that it shall probably be utilised as the myocardial perfusion PET tracer of choice[35].

A major limiting factor in utilising cardiac PET in the UK is the cost of firstly acquiring, and then maintaining, an expensive PET-CT scanner and the challenges of utilising it for both oncology and cardiac imaging. Other challenges include the costs in purchasing the strontium/rubidium generators (£25,000 per generator and 12 required per annum), which greatly limits its widespread use and perhaps restricts usage to specialised cardiac units.

It is also undergoing major challenges from some clinicians' preference for more available SPECT or MRI, making the extra cost for PET-CT difficult to justify. Currently some prospective, multicentre trials, for example, SPARC[36], are underway to evaluate the prognosis and resource allocation of coronary CT, cardiac SPECT and PET.

Conclusion

Cardiac PET has the potential to play a key role in the armoury of non-invasive tests available to the clinician to accurately diagnose coronary artery disease. In comparison to SPECT imaging, it is faster, has a lower radiation dose[37], and produces better quality images with a higher spatial resolution and fewer artefacts. This is all performed more conveniently for the patient in one visit to the hospital, as opposed to two separate visits.

Cardiac PET also yields important information regarding myocardial blood flow, which helps to resolve equivocal coronary artery stenoses, and in particular, balanced three vessel disease. The utilisation of coronary calcium scoring and hybrid imaging does, however, require more evidence-base before routine usage, but shows great promise for the future.

Whether a hospital utilises it or not would depend heavily on the local expertise, the clinicians' preference and the availability of a PET-CT scanner. Cardiac PET and PET-CT shall, however, remain a very important and appealing cardiac functional imaging test for patients.

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{ 50 } X RADIOLOGY IT: MOVING ON FROM PACS

ANANT PATEL

In 2012, the Commissioning Board's Informatics Chief wanted a commitment for the NHS to go paperless by 2015[1]. This year the Health Secretary[2] indicated that the NHS should be paperless by 2018 to save billions for service improvement and help meet the future needs of an ageing population. Who knows if a later target will be offered next year?

Slippages like these are the norm in public sector as the published timelines are often described as ambitious. The form of healthcare that will be needed to fulfil these ambitions is currently known as health informatics (evolved from medical informatics), which is designed to send accurate information to the correct person at the right time[3]. This article will discuss a few of the emerging aspects of informatics that may affect diagnostic imaging in the future.

The true origin of imaging informatics

The success of Picture Archiving Communication Systems (PACS) worldwide has embedded and pushed radiology within UK informatics departments to the forefront, overtaking one of the original types of clinical information systems (CIS), ie Laboratory Information Management System (LIMS), due to the use of digital images[4]. The clinical division of Pathology was formerly the CIS that pioneered request referrals known commonly as 'order comms' which are basically structured electronic messages. However, the requirements for radiology-related systems have been prioritised increasingly over LIMS desires due to the complexities of dealing with a patient in real-time and at a specific location (imaging department), rather than a pathology sample that can be processed anywhere. Also, the need to consider the Ionising Radiation (Medical Exposure) Regulations have superseded LIMS requirements for systems such as GP electronic requesting. I have been involved with two joint laboratory/radiology order communication related projects where radiology requirements have over-ridden LIMS requirements for the above reasons; the LIMS suppliers were unable to meet the relatively more complex radiology needs and flows with various radiology information systems (RIS). This may now change unless imaging departments are aware of what may happen in the future with the current push in informatics for cost savings as well as improving patient care.

Many Trusts in the UK have imaging departments with long established information systems such as RIS and PACS, along with voice recognition (VR), and other tools and applications. Some Trusts have incorporated the above systems into electronic patient records (EPR), which are digital data within a particular Trust/hospital. This is the direction that Tim Kelsey[1] of the NHS Commissioning Board and Jeremy Hunt[2], the current Health Secretary, are advocating. However, already two steps ahead of the electronic patient records system is the electronic healthcare record (EHR). It should be noted that the EHR is being muted as the way forward since it will enable the digital capture of information from 'the cradle to the grave', initially with patient access via a clinical portal. Furthermore, the EHR is not just confined to a hospital record but one that should include GP, NHS and Social Service systems except when an individual opts out. It has been suggested that patients will be able to download their GP held information using a concept similar to the 'Blue Button' developed by the US Department of Veteran Affairs[5].

"Already two steps ahead of the Electronic Patient Records system is the Electronic Healthcare Record"

Downloadable data will be personal health information, such as self-entered data and results held by the system, and can be downloaded as a text or PDF file after the necessary authentication. This will be trialled initially with GPs[6]. As well as textual information; this could include key radiology images, similar to the way some patients are given radiology images on CDs, but with more healthcare data. However, unless the record is easy to use it will not be successful, and the take up will be low, which was the downfall of a recent attempt called HealthSpace (launched by the NHS in 2007), where patients found it too difficult to create an account and even to log into[7].

The integration of RIS and PACS into EPR is a natural progression to enable order comms (requesting and results messaging) from primary (GP) to secondary care systems and vice versa. EPRs also allow applications such as scheduling (appointment bookings) to be used for various departments, ie for radiology, outpatients, therapies etc, giving authorised users in radiology access to a patient's non-radiology appointments. This enables the connecting of data to allow opportunities in healthcare which will increase productivity (successfully achieved with PACS), safety through having access to accurate records, quality of data improvements, more accurate analytics (data analysis) and hopefully decision support (tools to help make clinical choices)[8].

Many imaging departments are now 'paper-light' or paperless and are in a strong position to influence the rest of the acute sector CIS with the lessons learnt. However, having multipurpose systems that can be used in various departments (enterprise-wide) such as scheduling, non-radiology order comms (requesting and reporting pathology/cardiology/endoscopy/audiology etc) could reduce the functionality required in a RIS. This approach is currently influencing the present wave of PACS procurements, as Trusts that have merged, or are about to merge, need to provide a quick common cross-site reporting work flow, that may not be able to wait until a trust-wide radiology compliant EPR or RIS can be deployed. Hence, a PACS-centric reporting workflow would circumnavigate the need to adopt an EPR or RIS that may not be have the same specification as more specialist non-EPR RIS. As long as the EPR is still patient-centric then PACS-centric (reporting in PACS), as opposed to the common RIS-centric flows may be used successfully in the future. Providing there is interoperability with the future EPR of the merged Trusts, there would be clear benefits of being able to quickly deploy a merged reporting radiographer/sonographer/radiologist solution that could be used across all sites.

"Twitter is the mostly likely social media platform to be used in health informatics"

Currently, multidisciplinary team meetings utilise anything from a PACS to images stored on portable media (CDs or secure hard-drives) to access images and radiology reports. The additional information from an EPR (pathology results/future diagnostics and appointments) will further link professionals and enable them to access instantly other analytics. The driver for more locally delivered projects to cater for the community will expand the concept of multidisciplinary team meetings to a wider group of professionals who need to access data from various unconnected systems, probably via a clinical portal (a central access point to appropriate data). This can be adapted to suit the needs of users in a community, linking together data that are kept in 'silos', enabling the right people to access relevant applications, data and services[9]. Initially, this will probably not be a single seamless record, but a way of 'dipping' into the silos of information to retrieve relevant data, be they images or textual records. To ensure portals work, the use of standards, frameworks and implementation guides suggested in the Interoperability Tool Kit[10] may help. This is not a piece of software or a product but a focus on the business needs of local organisations and communities. Currently, EPR and GP systems are being linked through a Health Information Exchange to allow real-time access for GPs and healthcare professionals for improved health outcomes[11]. This allows a GP to access a patient's local EPR and for Trusts to access GP records after the relevant data sharing agreements have been agreed between the relevant groups.

Implementation of any healthcare technology is a 'group and communications' activity, where feedback is required and quality assurance should be performed technically and socially[12]. This has occurred within radiology via a number of different media such as emails from the Society of Radiographers to members, via non-radiography groups such as the informative weekly NHS Networks email digest, websites (E-Health Insider), and forums such as the extremely successful UK Imaging Informatics Group. Although there has not been a successful central authority that has managed to act as a single point of reference, the National Allied Health Professions Informatics Strategic Taskforce had tried to lead, advise and form understanding. Finally, regarding communications, Twitter is the mostly likely social media platform to be used in health informatics, if the organisations give staff the relevant access. This could be used for real-time patient feedback, keeping patients and staff informed, patient education, and enabling followers to be exposed to similar organisations[13].

Economic options

Some healthcare organisations have implemented open source healthcare applications, which have massive cost savings as long as staff are available to support the application. Open source software and applications are developed collaboratively and are 'freely available'[14]. Hence the deliberate use of the 'conceptually similar' Wikipedia for this reference, which many academics will not take seriously for information accuracy. However, the sources at the bottom of the Wiki are useful and more informative than a Google search, which is the most popular form of searching for information. It should be remembered that the open source concept was used for developing network protocols for the World Wide Web and Internet with free licensing, which has, of course, revolutionised healthcare, as well as virtually everything else we know. It is a lost opportunity with the recent PACS procurements, as there are solutions available that may not be as polished as the commercial products but are fit for purpose. Furthermore, they are being used in many institutes internationally, for example, using OsiriX Foundation on Apple Mac operating systems[15]. If one were to invest time and resource staff (centrally) a variety of free imaging software is available[16] and this would have massive cost savings as organisations would have to invest only in implementation, integration, support, training and development, and not for the pockets of the shareholders of the PACS/RIS suppliers. However, the following ingredients are essential: expert advice; good quality software; maintenance of the software; and ensuring licensing laws have been followed correctly[17].

An organisation that is ready to invest some resources into exploring this can implement a system at a fraction of the cost of commercial

> "INFORMATICS REQUIRES LONG-TERM INVESTMENT BEFORE SOCIO-ECONOMIC RETURNS ARE REALISED"

'off-the-shelf' solutions, and drive down maintenance and other charges. Unfortunately, the products cannot currently compete against the reluctance of informatics departments to explore such avenues, as it is easier to pay a supplier a large amount of money to manage such a product in the short to medium-term than invest for the longer-term. Surprisingly, data protection and confidentiality in such systems are deemed more secure than commercial products[18], however, the fear of who exactly will support the system is the biggest concern if there is an issue. That said, the 'paid for support' provided by some large companies leaves a lot to be desired.

The introduction of mobile technology (laptops/tablet/mobile phones/ digital pens) within radiology has been questioned but has proven useful for reference, learning, consultations, communications with patients, and diagnostic reading[19]. However, most of the high quality applications are available only on the iOS platform (Apple), with the expectation that the other platforms such as Android will catch up soon. Applying them directly in a PACS/RIS setting is still to be demonstrated within the UK, though Bulmer[20] has recently hypothesised their use, and listed advantages as being the possible reduction of paper, help with checking in patients, and signing consent forms. There is also the current risk of bringing your own device (BYOD) be it laptop/tablet/smart phone to accomplish an activity, but also possibly bypassing your organisation's systems and processes. This, along with using powerful collaborative applications and social media, poses risks to data security[21].

The future

The House of Commons Select Committee[22] reported that lessons have been learnt from various national programmes involved in developing electronic patient records and, as a consequence, identified the need to focus on ensuring local involvement in delivering projects. It must be reiterated that informatics requires long-term investment before socio-economic returns are realised, which may be qualitative rather than quantative. Implementation will continue to be problematic in terms of change management, due to claims about the benefits of the information technology not being believed by healthcare professionals and the forgotten administration and clerical staff[12]. Based on personal experience, when a paper-light EPR system has been fully operational for a number of months and the system becomes unavailable for a day or two, users will probably go back to their paper contingencies. It's only then that the users realise and appreciate the benefits of the system, even if it has workarounds.

The current economic climate is an added complication in that Trusts taking a systems approach when selecting IT solutions may compromise on the clinical information solution, ie it may not be the best of breed but will fit the current systems. Hence developments will continue to be less revolutionary than the National Programme for IT, but more iterative in the sense of local developments that, if successful, will probably be shared slowly, as there will probably be very few mechanisms of sharing of good practice. There will be reliance on the communication methods stated previously and on the advice of current users of systems and suppliers of the products.

Conclusion

In reality, target dates for going 'paperless' may change, as shown by both Kesley[1] and Hunt[2], but this will give some time for realising such a huge project, particularly with the constraints that are inevitable with the current economic climate and the uncertainty of the outcome for 2013 NHS reforms. Brave choices will still need to be made in the acute sector if EPR/EHR and other innovative systems are to be adopted; these may not necessarily be the best CIS but may be ones that have a high level of almost seamless integration by 'talking to' the EPR and other health informatics systems.

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"A VARIETY OF FREE IMAGING SOFTWARE IS AVAILABLE"

{56} FUNDING AND COMMISSIONING ISSUES FOR UNDERGRADUATE AND POSTGRADUATE HEALTHCARE EDUCATION FROM 2013

VIVIEN GIBBS, MARC GRIFFITHS

THE MODEL OF HEALTHCARE TRAINING, WHEREBY THE NATIONAL HEALTH SERVICE (NHS) HAS RESPONSIBILITY FOR PROVISION, IS DISAPPEARING. THE FUTURE DIRECTION IS THAT OF EDUCATION PROVIDERS NEEDING TO RESPOND TO COMMISSIONERS' REQUESTS AND BEING ABLE TO EVIDENCE THE CAPABILITY TO TRAIN[1]. THE INTENTION IS TO ESTABLISH A CLEAR LINKAGE BETWEEN THE EDUCATIONAL NEEDS OF THE FUTURE HEALTHCARE WORKFORCE AND IMPROVED PATIENT OUTCOMES, ALONG WITH DEVELOPING A FLEXIBLE APPROACH TO PROVIDING QUALITY PATIENT CENTRED CARE[2].

Training institutions will have greater accountability for the education of the future healthcare workforce, particularly with regard to quality metrics. There will be a requirement for an innovative approach to be adopted in terms of learning, teaching and assessment pedagogies, and the training provision will have to constantly evolve to meet the changing needs of the healthcare workforce. Individuals being trained now will need to be flexible, willing to continuously learn and develop, and be more comfortable with technology and change than any previous set of graduates[3].

Education providers of the future will need to lead the way in improving the quality of education and developing innovative training. Radical changes to the way the service is commissioned in the past have resulted in similar requirements to adapt educational provision, and providers will need to learn from these experiences. The requirement to move towards a more commercial model, and apply this to the NHS educational setting, will mean that examples from the private sector will need to be reviewed.

Providers of education for the allied health professions (AHPs) will be required to recognise the need to support the whole workforce, from assistant to consultant level, mapping against the clinical domains outlined in the *NHS Outcomes Framework* publication[3]. This will involve clear identification of preceptorship, mentorship and lifelong learning in the form of continuing professional and personal development (CPPD). Importantly, radiography as a profession will need to model future workforce education and training around the adoption of new technology, research and innovation, and further promote itself within the realms of academic and clinical practice. The introduction of Local Education Training Boards (LETBs) and Academic Health Science Networks will also have integral roles in the translation, development and provision of new curricula, whilst ensuring involvement and appropriate scrutiny from the relevant regulatory professional bodies.

Background

The abolition of the ten Strategic Health Authorities (SHAs) in England has significant implications for NHS workforce planning and for the future education, training and professional development of NHS non-medical staff. Prior to 2013, nursing, midwifery and allied health profession education in England was provided via a national standard contract between the SHAs and individual universities, which ran faculties or departments that specialised in particular NHS professional education and training, and were approved by the relevant professional body[4]. The SHAs were therefore the planning and awarding bodies for these education and training contracts in England.

Funding for nursing, midwifery and allied health professional education (known as NMET; non-medical education and training budget) was one component of the 'Multiprofessional Education and Training' (MPET) budget, which was included in Department of Health (DH) funding of the SHAs. Other components provided funding for postgraduate medical and dental education (MADEL). MPET funding was allocated for NHS workforce education and development for all areas other than for medical training and courses. The Higher Education Funding Council for England (HEFCE) allocated student numbers to universities for medical training and courses, as well as for dentistry, pharmacy and healthcare science[5]. MPET funding for nursing, midwifery and allied health profession education provided for pre-registration education, post-registration education, and continuing professional development (CPD).

The SHAs managed MPET budgets according to national, regional and local requirements in terms of workforce planning. Universities were contracted to provide courses and had to meet certain criteria. For their part, universities would plan and manage the viability of course programmes, and ensure their staffing by appropriately clinically qualified and academic staff and associated clinical placements. They were also required to meet standards and regulations set by the relevant professional health bodies, and they had to match these requirements with commissioned numbers[6].

MPET funding covered allied health professions such as radiographers, physiotherapists, and podiatrists, where specific arrangements related to registration apply. For example, radiographers must be registered to work in the NHS. For this, they need a degree or equivalent in radiography from an education centre approved by the Health and Care Professions Council (HCPC) (formerly the HPC). All qualifying radiography courses since the early 1990s have been at degree level, and most are three-year courses. Students are normally based in a university and in hospital departments for an equal amount of time.

Since the transition of healthcare education to higher education institutions (HEIs), universities have had significant resources (staff) and capital investments in NMET/ MPET contracts, and have employed academic staff who were experienced practitioners in their field. However, the DH in England signalled that the MPET budget would be cut by up to 15% over three years, commencing in 2011/12. SHAs in England confirmed that the number of training place commissions was likely to decrease by around 10-15% and that these cuts would be 'front ended' ie with the greatest reductions in year one (2011/12). Within this overall reduction, there were considerable variations amongst the SHA regions and within individual professions, with some areas (such as physiotherapy) receiving even larger cuts over the period. At present there appears to be a wide level of variation in the number of students being commissioned in different regions[5].

Prior to 2013, some universities received approximately 25% of their total income from NHS funded health professional courses. Uncertainty about the arrangements for the commissioning and award of these contracts from 2012/13 created a financial problem, which coincided with the introduction of the new fees and funding regime for other undergraduate courses in England. With further anticipated reductions in student numbers, many universities had no option but to implement redundancies for well-qualified and experienced staff.

The new model from 2013

The Government launched its White Paper *Liberating the NHS: Developing the healthcare workforce* in January 2012[7] and this set out proposals to

> "This will include the mapping of particular 'at risk' specialist roles, such as nuclear medicine and ultrasound"

establish a new framework for workforce planning. This was to ensure high quality education that supports high quality and safe patient care. In preparing its White Paper, the Government had several objectives:

- Value for money;
- Widening participation of those accessing the education;
- Ensuring that there are the correct numbers of people being trained with the appropriate skills;
- Increasing responsiveness to patient need and changing models of delivering healthcare;
- Delivering high quality education and training.

Various regional consultations were subsequently held on the workforce White Paper, with stakeholders from the NHS, education providers, local authorities, patients and the public. The outcome of these consultations supported the proposals in the paper to create a new provider-led system with greater autonomy, and local trusts were given responsibility for planning the education and training of their workforce. The new model consists of an overarching board associated with each Trust, known as a Local Education Training Board (LETB)[7]. These boards are accountable to Health Education England (HEE).

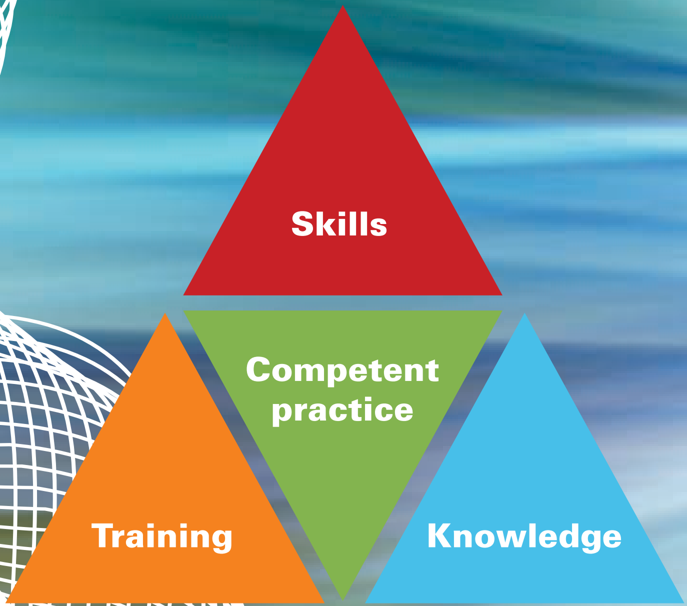


Figure 1: Requirements for competent practice.

"HEIs and NHS clinical sites may need to collaborate more extensively"

SHAs remained accountable for education and training until 31 March 2013, after which they ceased to exist. HEE was established as a special health authority in June 2012, became operational from October 2012, and fully functional from April 2013. This newly formed HEE is intended to provide a multiprofessional oversight of the new system. It replaces Medical Education England (MEE), which previously covered medicine, dentistry, pharmacy and healthcare science, the nursing and midwifery professional advisory board and the allied health professional advisory board. This proposal has potential risks for the smaller AHP group, which could potentially be subsumed by the interests of the larger medical education and nursing bodies.

The LETBs nationally have common terms of reference. Ten principles were established to enable LETBs to develop locally appropriate arrangements, whilst operating within a nationally consistent framework[8]. These operating principles are designed to reinforce autonomy for local areas, whilst enabling high quality education and training for the workforce to ensure the best outcomes for patients and service users.

The ten principles consist of:

1. Local decision making;
2. Inclusive approach of providers;
3. Good governance;
4. Sound financial management;
5. Stakeholder engagement;
6. Transparency;
7. Partnership working;
8. Quality and value;
9. Security of supply;
10. Accountability.

Concerns

There are considerable concerns as a result of the abolishment of the SHAs, and what is seen by many as the failure of the DH to assign clear responsibility for the future planning and commissioning of MPET and NMET education and training. The policy framework set out in the document, *Liberating the NHS: Developing the healthcare workforce*[7] on the future of education and training in England failed to dispel these concerns. In addition, there are significant concerns that the DH has proposed that the MPET budget for nursing, midwifery and AHPs should no longer fund post-registration and continuing professional development (CPD) provision, and that it will be restricted in the future to pre-registration programmes. This poses a further risk to the future viability and availability of this provision. Funding for CPD will not be ring-fenced and may understandably not prove to be a high priority for Foundation Trusts and GP consortia during a period of radical structural change. Healthcare providers will be required to deliver efficiency savings over a four year time-scale, and CPD will be an easy area to cut. It is very unclear therefore, how well the DH's proposals will serve the future needs of the NHS in terms of CPD, and particularly the skills training required to keep pace with developments in care and technology. This may potentially have serious implications for the training and development of the future healthcare workforce, in terms of being equipped and flexible to deliver quality care.

There remains uncertainty over the responsibilities of providers (GP consortia and Foundation Trusts) to participate in the LETB process, and how they will co-operate to identify future national workforce requirements. Numbers of healthcare professionals being trained each year requires a careful balance to avoid oversupply, which leads to unemployed graduates, and undersupply, which leads to shortages in the workplace. A strategic approach is therefore crucial to ensure accurate forecasts are made, particularly in relatively small areas such as radiography.

MPET funding previously included NHS professional development and courses for those such as healthcare assistants who wanted to enhance their skills. The DH proposal to remove funding for these activities from the future MPET budget, and to restrict the latter to pre-registration training, conflicts with the life-long learning agenda which has been identified as being of importance by the Government[9].

The transfer of the current planning and commissioning function of the ten SHAs to a plethora of local skills networks is a cause of further uncertainty in the future planning and commissioning of MPET/NMET provision. There is a requirement to make effective and efficient use of HEI facilities and infrastructure, and the need to avoid unnecessary bureaucracy and transaction costs within the NHS and HEIs. Neither of these concerns appears to have been addressed. Universities have been given little time to respond to these changes and many may not be ready for a transfer in responsibility. As a consequence they risk being left behind by more commercially aware, independent providers. This raises concerns that the quality and scope of the education and training for NHS staff that will be available, may be very different if driven purely by commercial concerns.

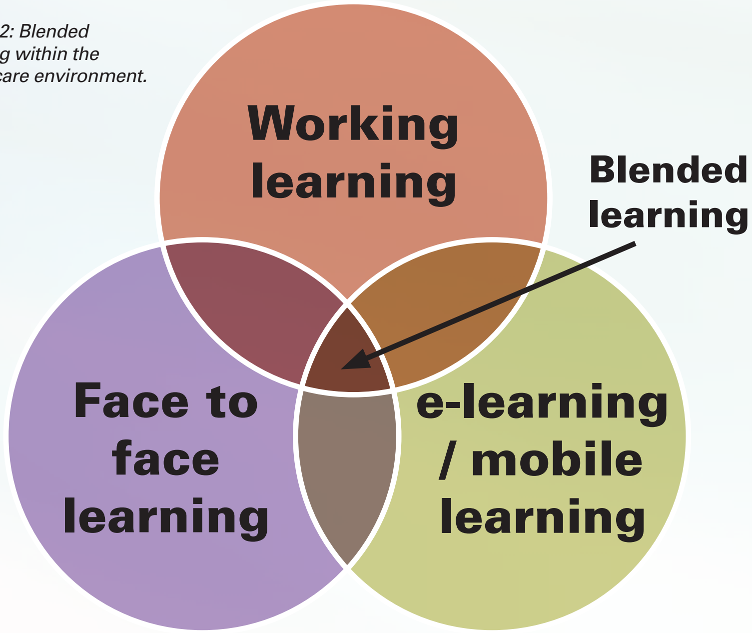
It is also difficult to see how the proposed arrangements will be cost-effective, add value or improve the quality of patient care. There is concern that the new provider skills network arrangements will create another costly layer of bureaucracy, and therefore future commissioning and funding arrangements must be transparent. This is particularly important for universities engaged in contracts related to nursing, midwifery and the professions allied to health, since medical numbers will continue to be allocated by HEFCE.

Opportunities

Given the impending changes to the commissioning of future healthcare workforces, it may appear difficult to identify new opportunities for training and education. However, greater modelling of the future workforce requirements is now being undertaken by the Centre for Workforce Intelligence, which aims to provide commissioners with greater clarity around future required numbers of healthcare practitioners. This will include the mapping of particular 'at risk' specialist roles, such as nuclear medicine and ultrasound, which according to the Home Office[10] and the Society and College of Radiographers[11] are not recruiting sufficiently to adequately provide a supply of clinical imaging services for the future healthcare needs of the population.

The mapping of knowledge, skills and training will need to be further integrated, in terms of HEIs, clinical healthcare environments, professional and regulatory bodies and Academic Healthcare Science Networks. There is also the need for clinical practitioners to be cognisant of their responsibilities and accountabilities, particularly with regard to lifelong learning, to facilitate an adaptive and progressive platform for competent practice (figure 1).

Figure 2: Blended learning within the healthcare environment.



The previous system whereby some hospitals were restricted in where they could send postgraduate students for training, due to SHA funding arrangements, will mean that the new process will be viewed by some as a positive opportunity. Competition from commercially driven providers of education may potentially increase the quality of provision, and clinical staff will have the freedom to select those providing high quality courses. However, pressures on budgets may result in managers choosing the cheapest option rather than the highest quality.

The traditional model of education delivery, which has previously involved mainly face-to-face attendance, will need to undergo a transformational change. The emergence of a culture which places innovation and sustainability at the core of the modern NHS is beginning to redefine how practitioners access learning and education. This is coupled to the finite resources now in place to provide financial support to undertake any form of post graduate training. Healthcare professionals themselves may be required to invest more of their own resources, in terms of time or funding, in order to access certain types of training. HEIs and NHS clinical sites may need to collaborate more extensively in order to offer a range of flexible learning approaches.

The provision of 'door step' delivery is an opportunity for HEIs to further develop, which provides benefits for the clinical workforce in terms of being able to access learning in the workplace, with minimal disruption and reduced travelling time. There is also the potential for a partnership approach to educational provision, with sharing of revenue to provide income generation for both the NHS Trust and the HEI. The use of a blended learning model, which may include a combination of face-to-face and asynchronous learning (eg e-learning), may also offer advantages to the clinical workforce, in terms of providing access to learning within time frames convenient to the individual learner (figure 2).

Conclusion

The radical changes that are underway for training of the healthcare workforce have major implications for both the providers of education and the employers of the healthcare workforce. Training institutions will have greater accountability for the education of the future quality of the healthcare workforce, and there will be a requirement for more innovative approaches to be adopted. Whilst there are numerous opportunities presented to improve training and education of the workforce to achieve improved quality of care for patients, many concerns exist over the outcome of these changes to the commissioning of undergraduate and postgraduate education. In particular, the reduction in funding for provision of postgraduate and CPD education are difficult to reconcile with the Government's drive to achieve a workforce, which is not only competent and capable, but also sufficiently adaptable and flexible to function in a rapidly changing environment.

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{62} RADIOLOGY IN HAITI: CHALLENGES AND REWARDS IN A DEVELOPING COUNTRY

BARB TOMASINI

Figure 1: St Damien's as it is today.

Figure 2: Gordon Stokes and Barb Tomasini with the first radiograph produced at St Damien's in October 1997.

Radiology in a developed country is challenging enough with its ever changing technologies. Can it be implemented successfully in a developing country such as Haiti?

In 1997, Project Haiti of Saint Alphonsus Regional Medical Center in Boise, Idaho, US was asked to assess the need for and possibility of establishing radiology at Saint Damien's Paediatric Hospital in Port au Prince, Haiti. Formed in 1995, Project Haiti supports the medical needs of Saint Damien's Hospital. A refurbished mobile x-ray machine had already been donated and shipped to Saint Damien's.

Was it functional? Was radiology needed, and if so, was it possible?

As a radiographer I was asked to go to Haiti to assess the radiology situation. It was an exciting and challenging opportunity and one for which I thought I was emotionally and professionally prepared.

Facts

Haiti is a developing country in North America's Caribbean with an estimated population of 10 million[1]. Extreme poverty is widespread throughout the tiny country. Around 80% of the population is below the poverty line and only 50% is literate. The average life expectancy is 60 years for a man and 63 years for a woman. Infant mortality staggers at 52 deaths out of 1000 live births and half the deaths in one day are children under the age of five. Tuberculosis, malnutrition and HIV are prevalent[1,2]. Housing predominantly consists of dilapidated shacks without running water, sewerage, or electricity. Very soon after arriving in Haiti I realised that nothing can prepare one for this extreme poverty.

Background to Saint Damien's Hospital, Haiti

In 1987, Father Rick Frechette, an American born Catholic priest, designed Saint Damien's hospice for the sick and dying children of his orphanage to separate the dying children from those who had a chance of survival. Since then, Saint Damien's hospice has evolved into a fully-fledged paediatric hospital (figure 1). Frustrated by the shortage of physicians in Haiti, Father Frechette applied for and was accepted to medical school in the United States. After obtaining his medical doctor degree in 1999, Fr/Dr Frechette returned to Haiti permanently to practice medicine and to minister as a priest.

From Idaho to Haiti

The reality of Haiti was stark. My comfortable life was far removed as I saw first hand poverty that was incomprehensible. As a radiographer at Saint Alphonsus Regional Medical Centre in Boise, Idaho, I can rely on having consistent, high quality technology, running water, electricity, and access to supplies and imaging equipment. At Saint Damien's the basic needs for radiology were elusive. Electricity was unreliable. Running water was scarce and unsafe. Water was delivered to the well twice a day and stored in buckets. The donated mobile was not working and beyond my skills to repair. The darkroom was a closet consisting of four bare walls.

With modern technology unsupported, critical thinking skills momentarily escaped me in the immensity of the challenge ahead. I questioned how anything could be possible here, especially in radiology where a solid infrastructure is needed and yet did not exist. My initial assessment was bleak: radiology would not be possible at Saint Damien's. Nevertheless, the following day I travelled with a group of Saint Damien's patients to a clinic for radiographs. Some babies and children were accompanied by parents so our medical transport in the back of a truck for 90 minutes in the hot sun was stifling. Since Haiti has no solid medical structure as a pay-for-service country, the clinic we were going to did not triage patients by medical needs. They were triaged by economical means and paying customers were x-rayed ahead of those without funds. Saint Damien's runs strictly on donations so the sick patients of Saint Damien's were x-rayed last. After four hours of waiting, our patients were finally addressed. One baby was so sick I questioned if she would survive. She was cyanotic, and her breathing shallow and congested. Her mother would pinch her, forcing her to take a gasp of air. Radiographs confirmed her severe condition — double pneumonia with cardiomegaly and tracheal shift. In a developed country she would be in an intensive care unit. In Haiti she rode in a truck bed for an all day excursion for a radiograph. In that moment my mindset changed to "we will do everything possible to have radiology available at Saint Damien's."

> "Paying customers were x-rayed ahead of those without funds"

The plan

Once home, word spread quickly throughout the medical community about Project Haiti's plan to implement radiology at Saint Damien's. Within six months, used, reliable imaging equipment was donated to our cause. Team members were selected based on expertise. A biomedical engineer was recruited to the team to repair the existing machine and to install the darkroom equipment. By October 1997 our medical mission team landed in Haiti with an x-ray department literally packed in 70 boxes and duffel bags. Our cargo was valuable and, in view of the instability in Haiti, United Nations soldiers escorted us and our equipment safely to Saint Damien's.

Our Project Haiti team went right to work. Gordon Stokes, the biomedical engineer, found a broken kVP wire in the mobile unit. It looked promising to be functional. Saint Damien's had installed counters, shelves, a sink, tap, and electrical outlets in the darkroom. Gordon began installing the countertop processor as I unloaded the remaining equipment: lead aprons, film markers, safelights, film envelopes, cassettes, viewing box, everything needed for a radiology room.

Radiology hours were set to operate with the backup generator at Saint Damien's, which reliably produced the electricity needed. Our first patient was selected based on her positive tuberculosis skin test. The radiograph would confirm not only whether tuberculosis was active in her lungs, but also if our equipment was functioning properly. The radiograph was technically perfect thus heralding the start of radiology at Saint Damien's Hospital (figure 2). In the following two weeks approximately 150 patients underwent radiography. The mobile unit was replaced in 1999 when a fixed unit was installed at Saint Damien's. Around 3-500 patients were imaged each month.

Self-sustainability

It is essential to achieve self-sustainability after implementing technology in a developing country. The goal for Saint Damien's to become self-sustaining in radiology was met after Project Haiti purchased new imaging equipment in Haiti from a local distributor. This had many advantages:

- Reliable implementation, training, warranty, repairs, and performance maintenance;
- Supporting the local economy through buying local;
- The technology matches the infrastructure of the country;
- Pride and ownership buying local;
- Radiographers understand the basic technology.

Figure 3: Father Rick Frechette (left) and staff unloading the mobile unit ready for use at the Cite Soleil slum clinic.

Figure 4: Sister Philomena Perreault taking a chest radiograph at the San Fil slum clinic.

The next step

As Fr/Dr Frechette's medical work spread beyond Saint Damien's, he set up portable clinics in some of the worst slums of Haiti (figures 3 and 4). Again frustrated, Frechette explained how he needed radiology capability in the slum clinics to make proper diagnoses of medical conditions seen. I devised a plan to purchase a lightweight, portable x-ray machine that could be carried from clinic to clinic. In 2000, I hand carried to Haiti a portable x-ray machine purchased by the radiologists of Saint Alphonsus. By learning Haitian Creole, I could convince customs in Port au Prince to let me through with the machine. Once set up, the staff were taught how to take radiographs with proper radiation protection, machine and cassette maintenance, and safe transport of the equipment. In the next three months the need for processing on-site became apparent. Critical thinking skills from our team in Boise designed portable canvas darkroom tents and Project Haiti purchased counter top processors and portable generators to provide power. Project Haiti sent an expertise team specific to this radiology need to Haiti. Once implemented, we taught the radiographers how to maintain and clean the counter top processors. They learned proper mixtures and disposal of the darkroom chemicals. Portable radiology in the slum clinics proved valuable for accurate diagnoses for those who otherwise had no access to medical care.

The New Saint Damien's Hospital

By 2005 Saint Damien's Hospital had outgrown its space and ground was broken for a new Saint Damien's Hospital. While designing the radiology department for the new hospital, digital x-ray imaging had become the gold standard of conventional x-ray imaging. It made sense to install digital equipment instead of costly film and chemical processing. Project Haiti partnered with another organisation to purchase a quality digital imaging suite for Saint Damien's. Radiation protection was mandatory, but as lead-sheeted walls were cost prohibitive, cement blocks were made on-site to create solid, 10" thick walls for the radiology department.

Earthquake

The decision to install thick concrete walls was fortuitous when a 7.0 magnitude earthquake struck Haiti on 12 January 2010 and the digital x-ray machine survived unscathed. In fact, it was imaging earthquake casualties within 45 minutes. Typically 15-20 chest radiographs were taken daily. After the earthquake, 80-100 radiographs were taken of horrific injuries consisting of extremity fractures, amputated limbs, thorax trauma, skull and facial fractures. Thousands of patients, adult and paediatric, converged on Saint Damien's for high quality medical care. With the only functional radiology machine and highly skilled medical staff and physicians, Saint Damien's quickly became the flagship hospital of Haiti post-earthquake and remains so today. Days after the earthquake, a US-based radiologist, Allen Rothpearl MD, offered his teleradiology service to Saint Damien's. All of Saint Damien's images are interpreted through his group's donated services. When a critical finding was identified on an image, Dr Rothpearl devised a text message and email system to be sent immediately to the paediatricians of Saint Damien's alerting them to the finding.

The future

Radiology remains successful at Saint Damien's Hospital, but the provision of ongoing training and education for the radiographers is vital. An exchange programme for Haitian radiographers to train in Boise, Idaho, is being considered. Currently, Project Haiti is expanding medical imaging to include ultrasound and echocardiography. In April 2013 the International Society of Radiation and Radiologic Technologists (ISRRT) will be conducting their first radiology education seminar in Haiti. This will serve to generate revenue, aid understanding and help raise the profile of Haitian radiographers and the service they provide.

Conclusion

Radiology is essential for informing appropriate medical care. By providing that diagnostic healthcare experience to Saint Damien's Hospital, we have shown that radiology technology is possible in developing countries. Critical thinking with a passion to help in underdeveloped countries is a positive option for interested and committed radiographers. It is challenging to see extreme poverty, but it is also immensely rewarding to contribute to the implementation of a radiology service in Haiti, and to sustain, bolster, and continue it for one of the poorest countries in our world.

To quote Fr/Dr Frechette: "If not us, who? If not now, when?"

Acknowledgement

Grateful thanks to my friends in the photographs for giving me permission to include them.

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Barb Tomasini is a radiographer with 35 years experience and has volunteered in Haiti since 1997. She campaigns passionately to raise awareness for radiology in Haiti and was the 2011 ASRT International Speaker's Exchange Award recipient at UKRC 2012. Barb will be presenting her work in Haiti at RSNA 2013 in Chicago.

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IS THE AUTOPSY DEAD?

GUY RUTTY, BRUNO MORGAN

THE GOLD STANDARD FOR THE INVESTIGATION OF SUDDEN UNEXPECTED DEATH THROUGHOUT THE WORLD IS CONSIDERED THE INVASIVE AUTOPSY, ALTHOUGH THE WORD 'AUTOPSY' ITSELF DOES NOT IMPLY NOR REQUIRE AN INVASIVE COMPONENT TO THE INVESTIGATION AS MANY MIGHT THINK.

"PUBLIC AND POLITICAL INTEREST GREW IN THE NOTION OF THE NON-INVASIVE RADIOLOGICAL AUTOPSY IN THE UK"

Several different systems have been put forward previously as alternatives to the invasive autopsy (referred to from now onwards as simply the 'autopsy'), although none has managed to gain sufficient interest to challenge the autopsy's position[1]. However, there has been steady growing international interest in the potential role of cross–sectional imaging as an adjunct or alternative to the autopsy. The reasons for this include the approach being more acceptable to religious and cultural groups, more acceptable to grieving relatives, the potential to yield greater diagnostic information particularly in trauma related deaths and the production of a permanent, auditable record of the deceased[2].

In 2012 two documents were released which allowed the United Kingdom to take the next step forward in considering a realistic alternative to the invasive autopsy for the investigation of both natural and unnatural death. The first was the joint collegiate document from the Royal College of Radiologists and Royal College of Pathologists, which provided a statement on standards for medico-legal post-mortem cross-sectional imaging in adults. This document stated that both Colleges agreed that cross-sectional imaging could be used instead of an invasive autopsy, but went on to issue guidance for the circumstances when such imaging could be considered and the roles of the radiologists and pathologists involved. It included an example protocol for the use of post-mortem computed tomography[3]. The second document, provided to the Department of Health, supported the views of the Colleges and put forward proposals for the introduction of a national post-mortem cross-sectional imaging service within the National Health Service[4]. What had led to the production of these two documents and where do we go now?

HISTORY

The majority of autopsies undertaken throughout the UK today are medico-legal enquiries. Radiological imaging has been part of medico-legal autopsy practice since 1896 when x-rays were first used as an adjunct to assist the investigation of a firearm related homicide[5]. Shortly after this, the use of x-rays became established in the investigation of medico-legal skeletal trauma and became accepted as a form of evidence both within the civil and criminal courts. As early as 1898 the capacity to assist with the identification of an individual was realised although it was not until 1949 that radiographs were used solely for the identification of the victims of a mass fatality incident[6]. Despite the widespread use of radiographs in autopsy practice, and the early use of computed tomography (CT) in medico-legal practice, first in the living in 1977[7], and then in the dead in 1983[8], it was not until Donchin et al's work in 1994 that it was proposed

> **"In the UK the autopsy rate is relatively high and CT is often proposed as a method of reducing autopsy rates"**

that CT could prove a possible replacement to the autopsy[9]. Similar proposals were made for magnetic resonance imaging; first by Brookes for children in 1996[10] and then for adults by Bissett in 1998[11].

Although these early pioneers had sown the seeds that cross-sectional imaging may have a potential place as a realistic alternative to the autopsy, it was not until several years later, aided by continued technical advancements and wider availability of CT, that the world woke up to this possibility. Driven initially by the work of the Virtopsy® group (*www.virtopsy.com*) and the eventual introduction of dedicated CT scanners into mortuaries such as in Scandinavia and the Victorian Institute of Forensic Medicine, Australia, the interest, experience and research evidence began to grow slowly. In May 2012, in Zurich, the International Society of Forensic Radiological Imaging was born, along with the first dedicated journal for what many now regard within the field as a new medical sub-speciality. International standards of nomenclature for publications and research have also been proposed[12].

POST-MORTEM CROSS SECTIONAL IMAGING IN THE UK

Despite being one of the first countries to propose the use of cross-sectional imaging as an alternative to an autopsy, it is fair to say that the UK has been slow to follow other countries in this rapidly expanding field of research and practice. Despite internationally significant research studies undertaken at Manchester, Great Ormond Street, Oxford and Leicester, problems related to funding and access to scanners, along with scepticism from the wider medical profession has lead to limited uptake of post-mortem cross-sectional imaging in the UK. However, having said this, the UK has taken a more critical look at what has been occurring elsewhere, and rather than rush in and introduce a system that is not yet proven to be equal to an invasive autopsy, particularly with regards to the ability to diagnose coronary artery disease after death, it took its time to consider the wider picture.

One of the first major steps in advancing the national perspective occurred in 2008 when the National Post-Mortem Imaging Board was formed within the Department of Health. Initially arising out of the work undertaken at Leicester for the Home Office, in relation to the safe handling of contaminated fatalities programme, and confined to the consideration of the application of post-mortem CT (PMCT) to mass fatality investigations, this group has expanded to encompass post-mortem imaging of both adults and children, natural and unnatural, civilian and military deaths with representatives of practitioners, researchers, coroners, Colleges and interested parties. Public and political interest grew in the notion of the non or minimally invasive radiological autopsy[13]. Local independent sector services started across the UK. Funding was made available through the Department of Health for two studies to consider the potential role of post-mortem cross sectional imaging for both adults and children who have died from natural causes[14,15]. Following this, a National Institute of Health Research funded project was introduced to consider the role of angiography with PMCT. The introduction of PMCT-angiography (PMCTA) *(figures 1 and 2),* be it cardio-pulmonary resuscitation based[16], whole body[17] or targeted[18,19], and the realisation of the importance of air as a contrast medium for the examination of coronary artery pathology, coincided with the final decision being made by the Department of Health to engage two professional groups to consider two important questions. The first was whether or not an autopsy was now required to investigate death or whether PMCT could be used instead. Knowing the views of the first group, the second group considered whether a national PMCT imaging service could be introduced to the UK. The documents formed of the considerations of both groups were released to the public in October 2012[2,3]. In releasing the second document, the UK became the second country in the world after Japan to propose a national rather than local or regional post-mortem imaging service. Interestingly the drivers for this are opposite. In Japan the autopsy rate is low, even for unnatural death, making imaging a practical solution to improve post-mortem investigation, whereas in the UK the autopsy rate is relatively high and CT is often proposed as a method of reducing autopsy rates[16].

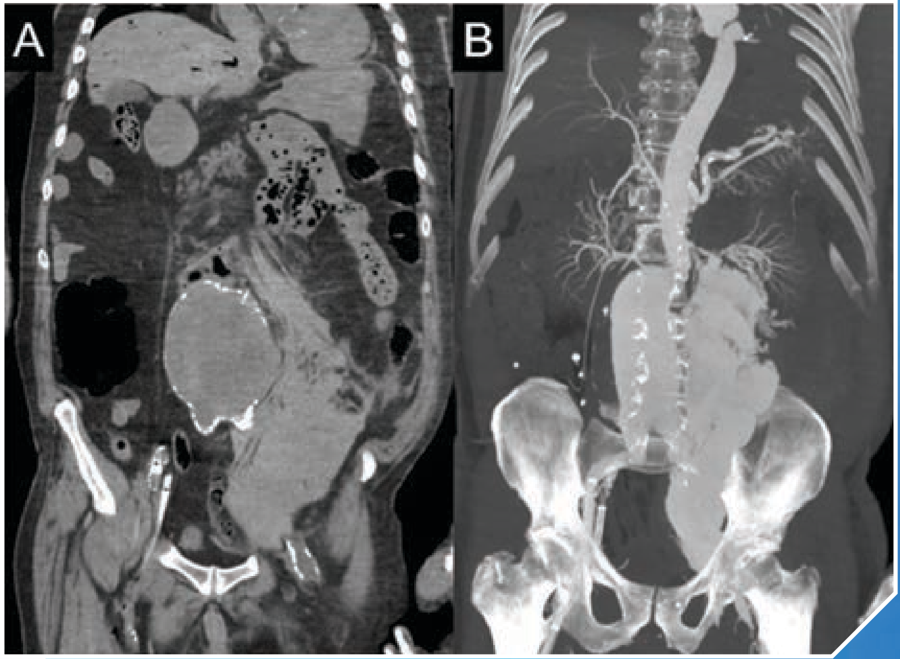

Figure 1: PMCT images of a sudden unexpected death due to rupture of an abdominal aortic aneurysm. (A) shows the coronal reconstruction of the non contrast enhanced scan and (B) shows a PMCT angiogram after infusion of intravenous contrast via a femoral artery catheter.

CHALLENGES AHEAD

So where do we go now? Currently, where cross-sectional PMCT services exist, or are starting up, they remain within the independent sector with the public paying privately for the service. However the UK, as with other countries across the world, is facing economic austerity and thus the introduction of a new imaging service, with additional capital and service costs, is not at the top of the Government's spending priorities. Thus, it is likely that the expansion that will inevitably occur will initially come from the independent sector, although it is anticipated that the proposed national service will ultimately be developed along the lines proposed in the Department of Health document.

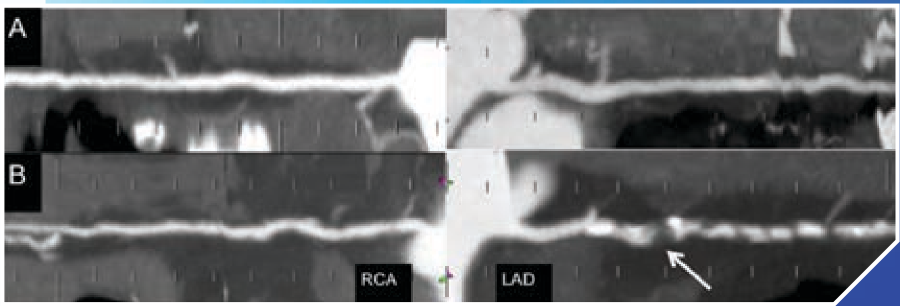

Figure 2: The coronary arteries can be demonstrated on PMCTA. (A) shows normal right and left anterior descending coronary arteries (RCA and LAD) in a case of traumatic death. (B) shows a case of sudden unexpected death related to coronary artery disease. The arrow shows a critical stenosis secondary to a mixed plaque.

Problems still exist in relation to access to scanners and the necessary UK workforce to run the service. Scanner access can be overcome by the introduction of dedicated mortuary based scanners to the UK as has occurred in other areas of the world such as the USA, mainland Europe, Scandinavia, Australia and Japan. However, this requires capital funding. Training programmes will be required as both the scanning of the dead, and reporting the subsequent images, is different to clinical practice. For example, many of the clues a radiologist uses to report clinical CT images are obscured in post-mortem images, such as oedema secondary to pathology being obscured by the oedema that developed as part of the peri-mortem process. This requires a full knowledge of the normal variations that occur as a result of death. A further difference is that, although radiologists are very familiar with using contrast enhancement dynamics to make a diagnosis, the pathophysiology of contrast enhancement is different in the dead. The introduction of College approved training programmes for radiographers, radiologists and pathologists will build up the necessary workforce for the service. The first introductory course to adult PMCT occurred in October 2012 in Leicester with further dates planned for 2013. Although these are not approved by the respective Royal Colleges as no college level training curriculum exists to date, at least this is a start.

Underpinning these developments is the requirement for research, as we are far from establishing the evidence-base required to consider removing the necessity for an autopsy in many types of death. Work continues in the field of PMCTA with the next field of development probably being the introduction of ventilated PMCT (VPMCT) to assist with the consideration of lung pathology after death *(figure 3)*. However, this work has only just begun.

CONCLUSION

It has taken more than 30 years since CT was first used in autopsy practice, and nearly 20 years since the first proposal of the cross-sectional imaging autopsy, for the UK to be in a position where it can realistically start to use PMCT as an alternative, in a limited number of circumstances, to an autopsy. These cases would include catastrophic internal bleeds such as ruptured abdominal aortic aneurysm, haemo-pericardium or haemorrhagic stroke. However, although a case of ruptured abdominal aortic aneurysm may appear clear cut, and the underlying cause may be natural; we emphasise that accident, suicide or even homicide have all been reported with people with a known aortic aneurysm and so interpretation must be done in the context of the scene of death, a detailed clinical history and thorough external examination. PMCT has an established role as an autopsy adjunct and a recognised role in mass fatality investigations for the purpose of identification and determination of the cause of death. PMCTA has taken us the next step forward and VPMCT will take us even further forward in realising this goal. The UK, in considering introduction of a national imaging service similar to Japan, is on the verge of the biggest alteration in the investigation of death since the time of Julius

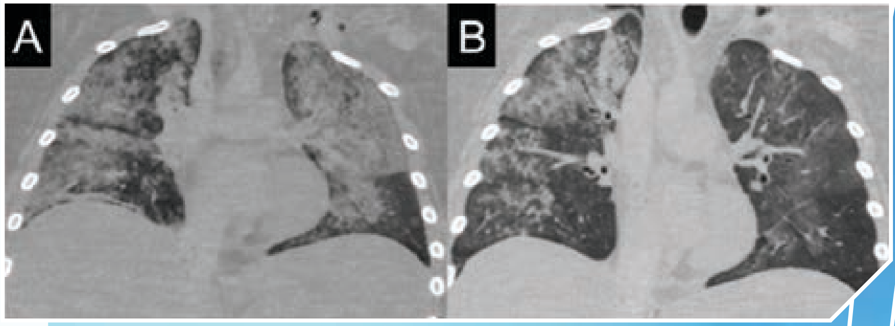

Figure 3: PMCT images in a case of pulmonary oedema secondary to drug death. Standard PMCT images (A) exaggerate the degree of pulmonary oedema similar to performing a clinical CT during expiration. Using ventilation during PMCT (B) mimics clinical CT during breath holding by expanding the lung, and potentially gives more accurate information.

"SCANNING THE DEAD AND REPORTING THE SUBSEQUENT IMAGES IS DIFFERENT TO CLINICAL PRACTICE"

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Caesar, and yet this is hindered by the country being in the worst economic situation for many years. We predict that this change will occur, but it is unlikely to occur, due to the economic situation, at the pace that those within the field feel it should. There is also a real risk that, as before, the UK will now be left behind by the rest of the world in terms of research, technical advances and service application, unless funding is made available to undertake research, install mortuary based scanners and train the future workforce.

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{72} BLAST IMAGING: THE BASTION EXPERIENCE

JO LEASON

"The experience military personnel gain during a deployment to Bastion is unlikely to be gained anywhere else in the world"

"Bleep bleep bleep" 5am shows on the clock face and my feet hit the floor before I am fully awake. Message on the pager '3 cat A ETA 10 min'. Into my uniform, boots laced up and, grabbing my glasses, I'm out of the door within a few moments and running towards the hospital through the pre-dawn light.

The ambulances are heading out to the helicopter landing site beside the hospital ready for three more injured personnel to be unloaded when the MEDEVAC helicopter lands. The hospital is only a short sprint from the accommodation and, as soon as I arrive, I head into the emergency department to check with the team leader what casualties we are expecting. The unmistakable sound of the Chinook helicopter coming into land can be heard nearby. "IED. Three coalition Category A casualties; two double amputations and an abdominal shrapnel injury" is the short response. It's a Sunday morning and another long day in Helmand is just beginning.

Figure 1: Hospital at Bastion.

Background

There are a very small number of full time military radiology consultants and, in conjunction with our Territorial Army and Royal Navy Reserve colleagues, we have been deploying since June 2009 to provide a radiology service in the UK-led hospital at Bastion in Helmand Province, South Western Afghanistan *(figure 1).* The focus is on trauma, with the majority of the workload caused by gunshot wounds (GSW) and improvised explosive devices (IED). A proportion of cases come from road traffic accidents and a variety of sports injuries, as well as the routine case load that a base of around 30,000 people produces. Two consultant radiologists, one from the UK and one from the United States of America, and six radiographers provide 24/7 cover to the emergency department (ED), theatres, ICU and wards. The patient base is made up of the International Security Assistance Force (ISAF), Afghan National Security Forces (ANSF) and a limited number of Afghan civilians. The hospital is equipped with two SonoSite ultrasound machines, four Dart digital radiographic machines and two 64 slice GE CT scanners installed in 2010 *(figure 2).* It has been described as the busiest and best trauma care in the world. Sadly, this level of care is due to the experience which has been gained in having to deal with the large numbers of severely injured patients passing through ED since 2006.

Figure 2: One of the 64 slice CT scanners at Bastion.

> "The off-shift radiographers are an even more critical asset"

In total, 52 nations work together across Afghanistan; in Helmand the majority of personnel are British, American, Georgian and Danish, and casualties from all these countries have been treated at Bastion. Since late 2012 there have been some announcements on reductions in troop numbers, but the 'enduring presence' numbers post-2014 have yet to be declared. As ANSF move into the lead operationally through 2013, the number of coalition (including UK and US) casualties is likely to reduce, but as Afghans continue to develop their capabilities, the numbers of ANSF casualties will proportionally increase. The operational tempo reduces over the winter season as the weather changes and also during the Islamic holy month of Ramadan when both the ANSF and insurgents fast. This is manifested as a reduction in the number of casualties over the winter months, but as the climate in Helmand is less extreme than in other regions of the country the fighting season lasts longer and, proportionally, the hospital remains busier than most other medical facilities in the country.

Casualties in Helmand are transferred almost exclusively by helicopter and the medical evacuation (MEDEVAC) is provided by a US or UK team; the hospital manning is similarly multinational. During my 2011 tour the team was British, involving all three services, US Navy, Estonian and Danish. At the time of writing, the US Navy has been replaced by the US Army and they will soon be joined by a Danish surgical team. This produces its own challenges in terms of different drug names, processes, acronyms and abbreviations. These often provoke a good deal of debate and laughter!

Ground evacuation is limited by the risk of security for road moves but also by time. Across the whole operational area there is a requirement for category A casualties (those with life, limb and eyesight threatening injuries) to reach a surgical facility within 60 minutes. As responsibility for bases is returned to the ANSF, the area that coalition troops are operating in, within Helmand, has reduced. As a result, the evacuation times are usually less than 30 minutes and the team at the hospital is alerted to casualty arrival by a bleep system.

The Bastion experience

Landing in Bastion for the first time reminded me a little of the experience of landing in India as a medical student on elective, combined with day one of my consultant appointment: heat, tiredness and the disorientation of arriving somewhere in the dark, combined with excitement, anticipation and nerves. Large amounts of adrenaline and coffee carried me through many of the long days and nights thereafter. At times when I felt so tired I could sleep for a week, caffeine and adrenaline continued to help me to focus my attention on the thousands of images of each full trauma CT.

Day one of a handover is always a little daunting; throw into the mix my first experience of a triple amputee in the ED, and by the time I fell into bed on the first proper night it felt like I had already been at Bastion for a week. The clinicians working here are almost exclusively consultant grades with the addition of a few senior trainees. The rotation is usually for an eight week period, which for some of the specialties with small numbers of consultants available to fill the plot (eg radiology), means the frequency of rotation is high, but the corporate knowledge base is also retained.

'Long days and short weeks' is an expression heard frequently and it definitely holds true. Days were long, especially as May rolled into June and the Helmand fighting season reached its peak. The majority of the 22 CTs we performed on one particularly memorable day were IED cases. Based purely on numbers this may not sound particularly intense when compared with a busy UK major trauma centre. However, if you include the mechanism of injury and the severity of the lower limb and pelvic trauma seen, it quickly becomes apparent that this sort of comparison is entirely flawed. Simultaneously managing numerous severely injured casualties with high velocity GSW injuries and multiple amputations would challenge almost all UK emergency departments; at times this occurred on a daily basis. The experience military personnel gain during a deployment to Bastion is unlikely to be gained anywhere else in the world and the skills and knowledge acquired are being taken back to the NHS where the majority of the clinical teams (both regular and reserve services) work while not deployed.

The radiology team is small and intensely cohesive comprising one consultant, no trainee and around four radiographers. In situations where the numbers are overwhelming with simultaneous casualties, calling in the off-watch second consultant is sometimes necessary and a good working relationship between the UK and US partners can make or break the experience. The off-shift radiographers are an even more critical asset due to the risk of burn out and only a major mass casualty incident would justify calling in the off-duty personnel.

The ED functions very differently to most regular UK departments. Offering continuous 'round the clock' care, the staff is supported and coordinated by highly experienced senior nurses. Every member of the team is absolutely clear on his/her role and responsibilities, and a scribe documents every decision contemporaneously. The orthopaedic and general surgical consultants are required to remain behind a red line until the ED team has completed the primary survey and the chest and pelvis radiographs have been taken. The radiologist is an integral part of the team. Their role is to perform the FAST scan (Focused Assessment with Sonography in Trauma), sometimes to confirm that there is no cardiac output, to review the digital radiographs and to coordinate and prioritise the cases for CT with the ED, anaesthetic and surgical consultants.

Provided there is no immediate requirement to take the patient to theatre, casualties will be transferred for CT with resuscitation ongoing. The old fashioned concept of 'too unstable to go to CT' has well and truly been disproved *(figure 3)*.

The early military experience of CT in Bastion followed the model developed in Iraq with a 4 slice scanner and a military teleradiology service providing support. With the installation in 2010 of two new 64 slice scanners producing 1500+ images per scan, the previous system was not sustainable or best practice: the bandwidth required to transmit the images and the time delay to an effective report to guide the clinical management were no longer acceptable and had to change. As a result, military radiologists have deployed to Afghanistan for the past three years with complete integration into the clinical team. Trauma scans are reviewed with the surgical consultants, the radiologist provides a report directly and clinicians benefit from the opportunity to discuss postoperative imaging and non battle injuries with a radiologist *(figure 4)*.

The UK involvement in Iraq and Afghanistan has resulted in an experience base with significant knowledge of blast imaging. While casualties from explosions are mercifully rare in the UK, the threats from domestic and

Figure 3: Resuscitation underway in ED.

Figure 4: Assisting in theatre with paediatric line placement (JL second from left).

"Primary fragmentation includes ball bearings, metal fragments, nuts and bolts – 'dockyard confetti'"

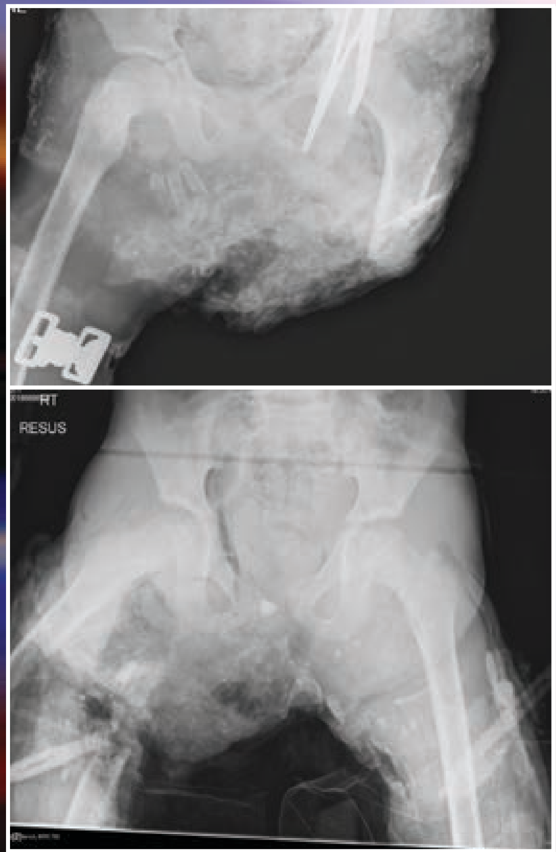

Figure 5: Paediatric traumatic amputation (5a right) and blast injury to pelvis and legs on a different casualty (5b below right).

international terrorism resulting in disruption to civil affairs and inflicting mass casualties indiscriminately is something which must be planned for. Most UK radiology departments may not think they will ever be faced by such injuries but Major Incident and MASCAL (mass casualty) planning, eg for the recent London Olympics, is now routine and the risk of similar injuries from industrial and other accidents always remains.

Blast mechanism

An explosion is an exothermic reaction initiated by a detonator that liberates rapidly enormous amounts of energy in the form of heat and high pressure shock waves. The blast wave is made up of a rim of compressed air under high pressure surrounding an expanding ball of explosive material. A high pressure wave propagates away from the centre of the blast causing movement of the air through which it passes, generating temperatures of 2000 to 6000°C and pressures of 1.4 to 3 million PSI. Blast injuries can be described in four main categories: primary, secondary, tertiary and quaternary.

Primary injuries result from the sudden increase in air pressure as the blast wave travels through tissues depositing energy *(figures 5a and b)*. This is particularly marked where there is a gas/fluid or gas/solid interface. Injuries seen on CT include pulmonary consolidation, lacerations and pneumothorax, shearing injuries to the GI tract with small bowel lacerations, trauma to the gas filled sinuses and the auditory ear canal, cerebral haemorrhage and traumatic amputation *(figures 6, 7a and b)*.

Secondary injuries occur when fragments of the device or surrounding

Figures 7: Primary blast lung injury on radiograph (7a below left) and CT (7b below).

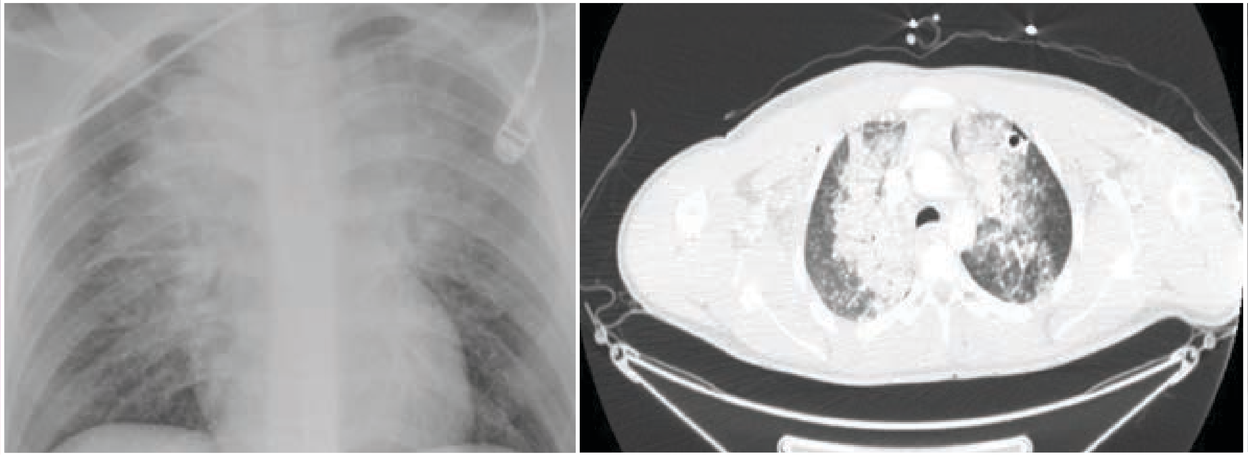

Figure 8: Fragmentation injuries to pelvis (8a), orbits (8b) and face and skull (8c).

Figure 6: Scout of traumatic amputations.

debris and soil are energised by the explosion and cause injury by penetrating trauma *(figures 8a, b and c)*. Primary fragmentation includes ball bearings, metal fragments, nuts and bolts – 'dockyard confetti'. Secondary fragmentation includes soil, mud, gravel and stones. Rivets and material from clothing, contents of pockets, pens, identification tags and bony fragments from other casualties are also seen. The effects of these fragmentation injuries have been significantly reduced by more effective personal protective equipment, which soldiers wear routinely. However, in a civilian incident these measures are unlikely to be in place and, during incidents in the UK in the past decade, secondary fragmentation has caused significant morbidity and mortality.

Tertiary effects result when the casualty is ejected or thrown by the blast wind and collides with nearby objects or is injured by deformation of a vehicle compartment. Blunt injuries result in injuries similar to those seen in conventional trauma with solid organ injuries including splenic and liver lacerations *(figure 9)*. Fractures of the long bones, skull and frequently occult vertebral compression fractures are seen.

Quaternary injuries describe the thermal effects of blast, toxic inhalation and post incident consequences. These are more difficult to attribute on the initial scan but may evolve over subsequent imaging if the casualty survives and during an ICU stay. Particular review areas on CT are the pulmonary arteries for early embolism formation, the orbits for globe disruption and fragmentation, gas tracking in the soft tissues, small subtle volumes of gas within the intraperitoneal or epidural spaces and vertebral column fractures.

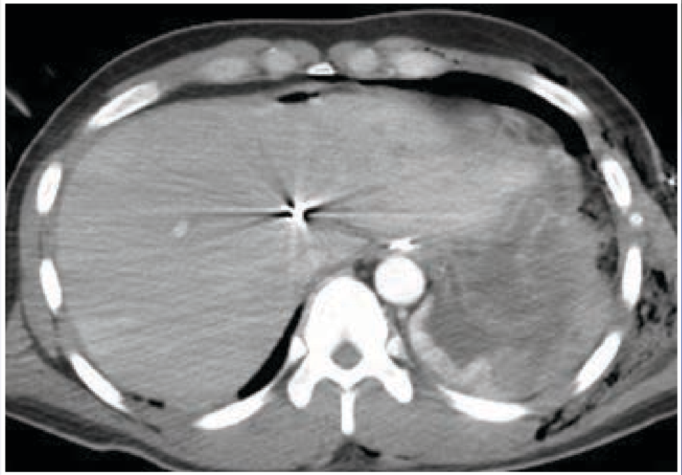

Figure 9: Hepatic fragmentation injury and splenic disruption.

In addition to human patients, experience has been gained in canine IED casualties with plain radiographs and CT being performed using paediatric contrast protocols *(figures 10a, b and c)*. An MDT format may also be used to discuss complex cases with the veterinary surgeons.

Conclusion

Ultimately, the classification of the injuries is somewhat academic. Understanding the aetiology does, however, ensure a good knowledge of the patterns of injury which are likely to result from exposure to a significant explosive incident. For the radiologist, it is essential to ensure that subtle occult, but clinically important, findings are not missed and patients receive optimal care at the start of their long journey to recovery.

The lessons learnt in dealing with the trauma cases coming through the doors at Bastion have resulted in tangible improvements and refinement to emergency medicine techniques. Although the work is often mentally and emotionally exhausting, our increasing knowledge and expertise ensures that the rates of military personnel surviving today would have been inconceivable in previous conflicts. Furthermore, those same lessons and techniques are being shared with the NHS and will lead to improvements in civilian care in the future.

Acknowledgement

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"THE RATES OF MILITARY PERSONNEL SURVIVING TODAY WOULD HAVE BEEN INCONCEIVABLE IN PREVIOUS CONFLICTS"

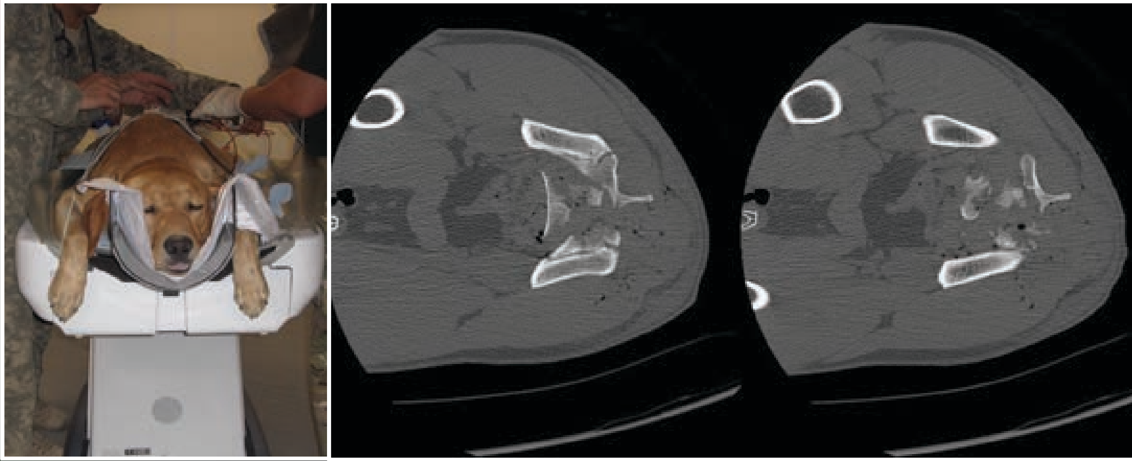

Figure 10: Canine awake sedation CT technique (10a above left) and sacral fractures – different patients (10b middle and 10c right).