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For imaging and therapy professionals

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Contents

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Foreword

There is currently unprecedented pressure on imaging and oncology services throughout the UK. As the population ages, the incidence of cancer, long term conditions and serious disabilities rise disproportionately. At the same time, new diagnostic tests and treatments emerge, often accompanied by unhelpful media headlines proclaiming these as the 'cure' for cancer, or the new gold standard test. The result is escalating demand and potential cost, both of which are unsustainable. The challenge, then, is to constrain demand, to that which is appropriate and necessary and to contain costs by increasing the effectiveness of service delivery.

The task is not impossible and pockets of good practice in various parts of the country demonstrate this. Examples of this are seen in the implementation of evidence-based care pathways, referral guidelines, multidisciplinary team working, skills mix initiatives, clinical leadership and independent sector provision. What is demanding is the need to identify the critical problems or deficits, to develop appropriate, sustainable solutions and to roll these out across the National Health Service quickly; in effect to bring about massive systems and cultural change within the NHS in short order.

Much work has already been done to identify the problems and deficits. In relation to cancer services, the National Radiotherapy Advisory Group (NRAG) report has been published and will be important in developing the cancer reform strategy. In diagnostic imaging, the process of identifying problems and deficits is still on-going but already it is evident that there are sizable skills gaps, such as supporting the delivery of non-obstetric ultrasound services. Solutions, or at least partial solutions, have also been developed, albeit not always to universal acclaim, particularly where these have involved contracting with independent sector providers of healthcare. The increased numbers of trainee radiologists, trainee oncologists and student radiographers, along with the increase in the number of linear accelerators and CT and MRI scanners over the past few years, have also contributed to the solution.

Inevitably, in a publicly funded system of healthcare, the charge of 'too little, too late' can be levied. Nevertheless, not insignificant improvements to patient waits have occurred, whether for diagnostic tests, or for cancer treatments. Sustaining these and improving still further is vital and, despite the sceptics, this challenge looks achievable. There is political will and public demand. Importantly, and as is clear from the work of groups such as NRAG and the National Diagnostic Imaging Board, healthcare staff also want change – the caveat is that it must be a real, transformational change and not 'just another re-organisation'.

A. Pitt

Andy Pitt
President
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Workflow in diagnostics and intervention – the quiet revolution

Richard Lyons

Introduction

What started many years ago as simple ergonomic changes in imaging system design to reflect and improve customer usage, have culminated in systems that are more influenced by the clinical use and the benefit provided than the technology employed. Technology for technology's sake often came with a price tag, an unnecessary complexity and a lack of user consideration.

Sense and economics prevailed as manufacturers adopted industry standard solutions, such as Windows™ based systems, and saw the potential beyond user-friendliness. Evaluation of the customer's desired outcome and how they achieved it led, through the appropriate application of innovative technology integrated with optimised processes, to improved workflow and outcomes. The term workflow, like solutions, once greeted with patronising smiles in clinical imaging departments in the United Kingdom (UK), is now used universally.

Why the change in attitude? The simple reason is that workflow improvements that are being achieved daily due to, for example, process change, the design of modalities and their integration with radiology information systems (RIS). Picture archiving and communication systems (PACS) and cardiac data management systems, even at a departmental level, are clearly differentiating the service provision of whole hospitals. Efficient core diagnostic services, including the diagnostic service provided by imaging departments, are essential to meeting government targets and to remaining competitive and viable, so are to be ignored only at peril. Some departments may consider that all they have to do is to wait for their ‘free’ PACS or RIS to achieve the levels of efficiency needed. However, it is not the distribution of images that provides the benefit but the transfer of clinically relevant information to provide guidance on patient management, and this latter requires much more thought if it is to be achieved.

Workflow and department design

Many institutions, to achieve the more significant changes that will improve quality of healthcare and drive costs down, are investing in departmental designs that suit patient workflows.
For example, at Southampton General Hospital (SGH) the approach has been to bring together what they see as the key components to deliver an enhanced cardiovascular service, namely catheter laboratories, cardiac magnetic resonance imaging (CMR), computed tomography (CT) and operating theatres. CMR at Southampton is now in the frontline for the management of ischaemic heart disease whereas, previously, it was used mainly for congenital and functional cardiac disorders. The patient presenting at casualty with chest pain has a prompt clinical assessment, an electrocardiogram (ECG) and an enzyme level check and, if appropriate, is sent directly to the catheter laboratory. A team is on standby to ensure the ‘door to intervention time’ is minimised and, overall, kept below the 90 minute guideline[1].
Should the preliminary investigation show that multiple vessel disease is present, the patient may be sent to have a stress cardiovascular magnetic resonance (CMR) scan to assess the viability of the myocardium and so help determine whether revascularization therapy would improve chest pain and the function of the heart. The stress CMR scan can also provide guidance on which artery to stent. An examination technique of measuring blood flow to the heart as well as late gadolinium enhancement (LGE), which takes approximately 30 – 40 minutes, identifies both ischaemia and non-ischaemia related cardiomyopathies, and necrosis caused by myocardial infarction 2. This diagnostic process ensures that costly interventional procedures and stents are only carried out where they are able to enhance the clinical outcome. Due to the close proximity between the CMR unit and the catheter laboratories, three to four acutely ill patients per week are now undergoing this additional stress MR examination.

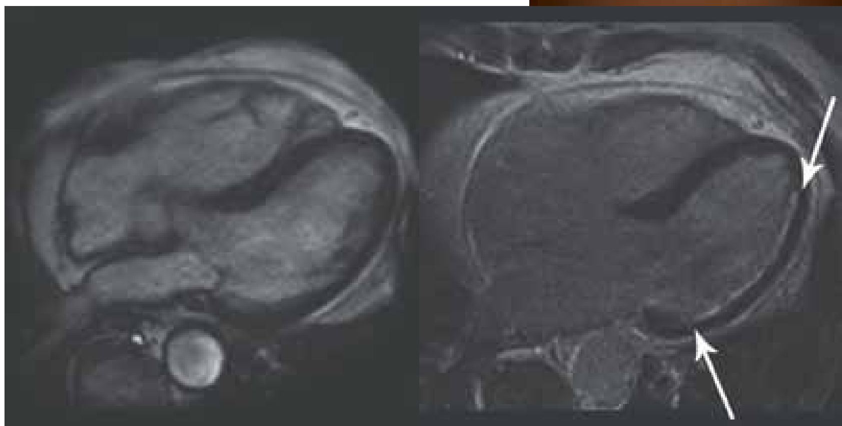

Figure 1. Cardiac MR examination: function (left image) shows wall motion abnormalities which correspond to the area of sub-endocardial infarct appearing bright in the delayed enhancement image (right image, and arrowed).

> ‘Technology for technology’s sake often came with a price tag, an unnecessary complexity and a lack of user consideration.’

Cardiac magnetic resonance imaging has been cultivated at SGH more than at many other UK sites, but not to the exclusion of cardiac computed tomography (CT) and CT angiography (CTA). These examinations provide a valuable service, for example, to those needing clarification on the extent of disease, or for patients prior to valve surgery to exclude coronary disease.
A particular SGH protocol which both reduces cost and improves service quality is provided for young women who have a non-invasive CTA to exclude heart disease, benefiting from the lower dose compared to catheterisation and the high, 99% negative predictive value of CTA[3]. The broader application of CTA to screen the 'at risk population' (because of family history, for example), will become less controversial as more sophisticated dose modulation techniques deliver much lower radiation doses, and are complemented by software which provides a discernible result quickly. Techniques such as ECG pulsing can now allow the user the discretion to reduce the period of full exposure during the diastolic phase, and to set how low should be the exposure to be delivered during the systolic phase.
Of the other limiting factors for CTA, namely temporal and spatial resolution, the limitation on temporal resolution in Cardiac CT has a more significant impact on patient care currently. All CTA scans on conventional multi-slice scanners require beta blockers to be administered to endeavour to reduce heart rate to a level that the systems can image; an important drawback for patient management is that it takes an hour for the beta blockers to take effect. The impact of such medication goes beyond the clinical and financial, affecting patients' abilities to transport themselves.

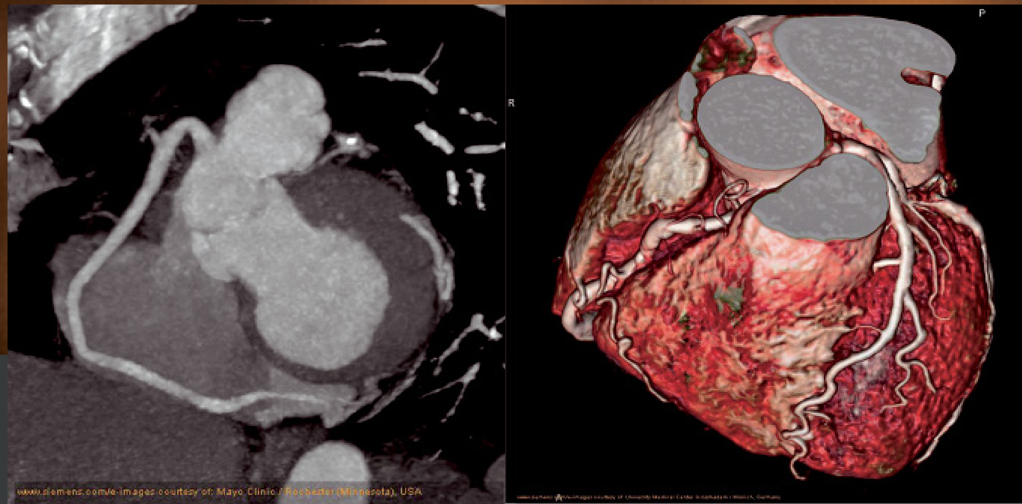

Figure 2. High spatial and temporal images acquired without beta blockers on a DSCT system

Papworth Hospital, another site centralising a significant part of its cardiac diagnostic capabilities, expects to overcome the beta blocker requirement and other limitations with a Dual Source CT (DSCT) scanner. DSCT provide consistent results with variable heart rates, atrial fibrillation, and asthma. DSCT can also cope with paediatric cases with heart rates as high as 144 beats per minute. Overall, the introduction of DSCT will make the total examination period shorter and provide an improved capability to deal with the full range of patients, including acute cases.
As cardiac CT and MR seem to be more and more capable of coronary and heart function diagnosis, does this mean the end of the line for other traditional modalities in cardiovascular diagnostic imaging? At present, no one is advocating this seriously and catheter laboratories still provide the most appropriate and economic procedure for patients with a high likelihood of disease[4].

The impact of change for staff

As systems, particularly in the catheter laboratory, have become more automated should there be benefit in terms of staffing levels? Many NHS hospitals are considering merging disciplines to deal with qualified staff shortages and improve financial performance. Different opinions prevail across the centres in the UK as to which role should disappear, with the choice generally between the radiographer and physiologist. The Cardiac Catheter Laboratory Practitioners (CCLP) programme that has provided flexibility in staffing whilst maintaining the specialist expertise of the individual disciplines is not (yet) implemented widely. A primary role of the radiographer in the catheter laboratory is to ensure overall image quality through selection of the correct angulation, collimation and minimisation of dose, often giving advice to the less experienced clinician on catheter type for the prevailing circumstances. Another aspect of the role is the importing of data from other modalities, such as CMR into the electrophysiology (EP) mapping system for atrial fibrillation, as well as data validation, quality control analysis (QCA) and post processing. Southampton has redefined the radiographer's role in a highly effective way, through sharing the specific knowledge of the catheter laboratory radiographer in terms of gating and the cross sectional imaging radiographer in terms of anatomy, to create universal cardiac radiographers with wider skill sets. Is it now time for the NHS to reflect industry organisational trends in process management and workflow by adopting a structure related to the disease rather than the branch of medicine[5]?

Meeting the challenge of increasing patient volumes

In cardiology, modern diagnostic tools are in place mainly due to recent government expenditure, but the linkage between imaging equipment and data management systems needs to be tighter if cardiovascular departments have any hope of keeping up with the ever-growing volume of patients. With more patients undergoing diagnostic care more frequently, conventional data management resources need to be updated to manage the images and information of today's leading technologies. Without an efficient work and data flow in place, it will not be possible to improve the quality of care whilst decreasing the costs for patients and healthcare providers alike. The integration of workflow and information is essential to achieve the efficiencies needed to address the growing demand for cardiology services. Perhaps it is necessary to turn to the United States of America (USA) to see really significant examples of the benefits of a fully integrated approach. The Heart Centre of Indiana (THCI) is such an example and is a totally digital centre, with a history of pioneering new clinical techniques. It carries the accolade of being the first freestanding US Heart hospital, established independently in 2002. The approach taken at the centre from the early design stage was an innovative patient-centric one, using lean process concepts in the design, such as having one room for the whole hospitalisation process with a universal bed – the patient does not move, rather, staff come to the patient.

> 'The term workflow, once greeted with patronising smiles in clinical imaging departments, is now used universally.'

THCI understood what technology could do for them and used it effectively where it improved their processes. Their patients have, for years now, booked appointments through the internet and received reminders for medication on their mobile telephones. These applications will sound familiar to those that know the goals of the Connecting for Health (CfH) programme in England. The clinical information system is a workflow engine combined with a computerised physician order entry (CPOE) system and a bar coded/radio frequency identification detection (RFID) pharmacy system; it incorporates PACS, and is universally available on-line within the single fully integrated system. The workflow engine ensures the many adverse events that beset hospitals are minimised. Incorrect medication and methicillin resistant staphylococcus (MRSA) infection are avoided through protocol guidance to nurses and clinicians.

THCI utilises smart health cards for patients and home monitoring to achieve high levels of efficiency. This approach culminated, within a few years of operation, in recognition as one of the top five healthcare institutions in the USA, with, additionally, five star ratings for heart attack, percutaneous coronary intervention (PCI) and valve surgery. Some metrics are shown in figure 3 to illustrate how THCI compares with the benchmark data laid down by the American College of Cardiology (ACC) in the context of percutaneous coronary intervention (PCI).

> The integration of workflow and information is essential to achieve the efficiencies needed to address the growing demand for cardiology services.

> Different opinions prevail as to which role should disappear.

Indicator	The Heart Center of Indiana	Benchmark (American College of Cardiology[6])
Average length of Stay	2.0 days	3.0 days
PCI Success Rate	99.4%	91.9%
Abrupt Closure	0.09%	1.3%
Unplanned Return to Lab	0.49%	1.0%
Door to Intervention Time	46.2 mins	90 mins
Mortality	0.58%	1.1%

Figure 3. Data for percutaneous coronary intervention: THCI compared to ACC benchmark data

Changing patient care

Once the diagnosis is established, what then? Interventional procedures, day case surgery and outpatient procedures in general have all contributed to the changing landscape of healthcare in the UK. Innovations in the technology of imaging systems, medical devices and clinical techniques have advanced together to widen the scope and effectiveness of these procedures. Specifically, today's technological advances in interventional angiographic systems are aimed at making both the technique and the workflow easier, in addition to improving the diagnostic information available. Some may consider this is the usual manufacturers' proposition – highlight expensive leading edge technology to improve the position for a limited patient group. This is not so; notable workflow improvements that enhance patient management and save costs can be obtained economically. For example, in the past it was often necessary to move a patient to CT to evaluate and master complications during an angiography-based intervention. Now angiographic CT, soft tissue CT-like, diagnostic information is available during angiographic or interventional procedures with the introduction of a low cost module. When bleeding occurred during the introduction of coils and stents to repair vascular weak spots, a patient would be transferred to the CT scanner to define the extent and location of the problem. Now the interventionalist can resolve the situation more quickly and avoid transferring the patient (a difficult task with the patient under general anaesthesia) to the CT scanner which is, typically, busy and non-sterile. This process, still the case in most hospitals, takes time and is costly, tying up both the interventional and CT rooms, and their respective staff. Providing angiographic CT imaging in the angiography suite supports the handling of difficult situations during interventional procedures.

Initial applications in neuroradiology imaging included the visualisation of local bleedings, the ventricular system, and tumours. This has expanded to abdominal applications, which include chemo-embolisation, radio frequency (RF) ablation, stent placement and vertebroplasty. Angiographic CT has improved patient management during interventional procedures by enhancing decision making using the additional cross-sectional information it provides. Although highly detailed images of the vascular system could be obtained previously, it is now possible to also visualise the soft tissue that surrounds the vessel (see figure 3), with the benefit of enabling the attending clinician to take fast and appropriate action and improving workflow simultaneously.

Changing benchmarks

The beneficial impact on departmental workflow from the application of technology can be seen clearly, but clinical workflow encompasses so much more. Simply getting the correct patient with the relevant clinical information at the designated time to enable diagnosis, timely treatment and follow up would be a major improvement. This can only be achieved if the information technology (IT) systems available to the healthcare practitioner go beyond the current patient administration systems (PAS) and provide real clinical workflow improvements.

The escalating pace of technological development in healthcare creates problems for researchers when trying to carry out longitudinal studies to assess the comparative clinical benefits of emerging systems and techniques against existing study benchmarks, whether cardiology or general angiography. This pace will continue with the added complication of the expansion of clinical IT systems, hybrid imaging and the introduction of molecular and other cellular techniques, such as stem cell research. The opportunity is there to improve radically clinical care and the efficiency of healthcare delivery in the UK; whether UK healthcare is willing to embrace such change is no longer the question, it is how and when will it do so.

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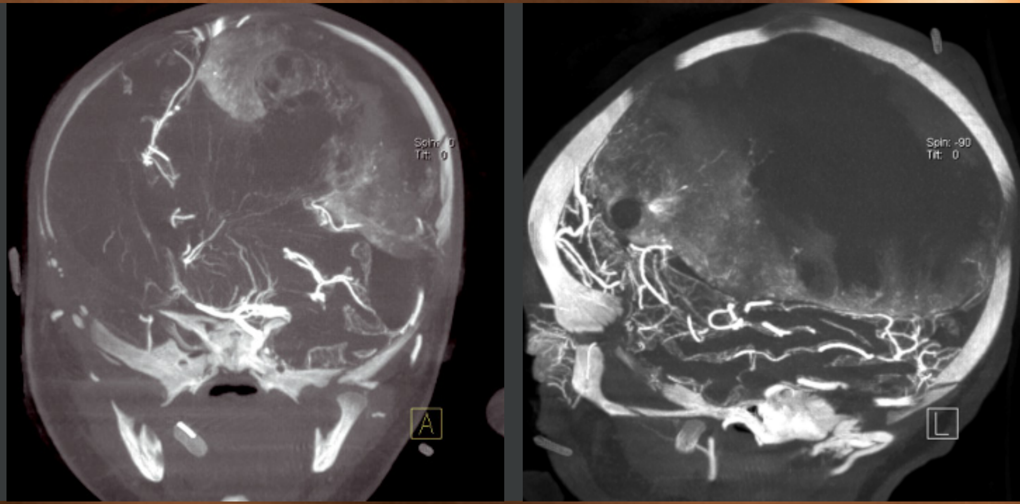

Figure 3. Siemens Angiographic CT (DynaCT) shows the diffuse and irregular enhancing tumour blush in the mass over the cerebral convexity. Furthermore, a cleavage plane between the mass and the underlying cerebral vessels is visible, documenting that the tumour is extra-axial in nature

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Richard Lyons, now retired, was latterly the marketing and communications manager at Siemens Medical Solutions, UK. He was involved in the radiology field with Siemens for more than 40 years.

Assessing the effectiveness of new technologies

Adrian K Dixon

Introduction

Rapid changes in the way in which healthcare is delivered continually necessitate different methods of assessing new technology. Economical issues have become paramount. Perhaps even more than mere fiscal assessment comes the need to avoid hospitalisation and reduce the number of patient contacts with expensive secondary care. Whether these financial imperatives are perceived by the patient as optimal often remains unanswered, even in these days of supposed 'patient choice'. The main methods of new technology assessment are discussed in this article, along with possible future assessments in the light of recent changes in the way in which diagnostics are being introduced into the United Kingdom (UK).

New technology assessment

The original hierarchical five level method of assessing new technology within the imaging field is now well established with only minor variations[1,2]. These are

- Technical performance;
- Diagnostic performance;
- Diagnostic impact;
- Therapeutic impact; and
- Impact on health.

Technical performance

The first level is that of technical performance, which assesses whether the new equipment or technique does deliver what it is expected to do on the technical front. For a new piece of diagnostic imaging equipment, this might assess whether or not the new machine yields anatomical images of spatial (and/or contrast) resolution equal to or better than existing equipment[3]. For nuclear medicine and other functional imaging techniques this might assess the additional physiological data that is obtained. For a new interventional stent, it might be a more mechanical assessment about tensile strength and biocompatibility.
For the average radiology department, there is little involvement in such assessments as manufacturers will not bring novel techniques or

> There should be no let up in the quest for even better techniques for identifying women at risk from this dreaded disease (breast cancer).

> Whilst the overall accuracy is very high (NHSBSP), this is based on the very large numbers of true negative findings in normal women.

technologies to the market place without all such technical performance information available. However, research departments become involved with assessments of prototypes, and some of these may have been developed by their staff members.

Diagnostic performance

Diagnostic performance, namely how well the new technique fares with regards to making the diagnosis, is often regarded as the be all and end all of technology assessment. It is often regarded, erroneously, as being synonymous with the diagnostic accuracy of the new technique. It is now realised that studies describing overall accuracy are significantly influenced by the prevalence of disease in the population under scrutiny. In fact, the markers of most importance are the sensitivity and specificity of the new investigation and these are often combined to produce a receiver operator curve for the new investigation[4]. Again, many prestigious research departments become involved in such early assessments. But of course, the prevalence of various disease processes in these institutions may be far removed from the real world of a typical general hospital. Hence, there is need for early, large, multicentre studies of new methodologies, which will include a spectrum of different practices.

The data now available from the very high quality UK National Health Service Breast Screening Programme (NHSBSP) provides interesting conclusions: whilst the overall accuracy is very high[5], this is based mainly on the very large numbers of true negative findings in normal women. The predictive value of a positive result is not all that high and this means that a fair number of normal women still have to undergo a traumatic biopsy. The sensitivity for some of the more aggressive lesions is rather lower and MRI may be better, especially in younger women[6]. Consequently, despite the considerable advances which have arisen as a result of the NHSBSP, there should be no let up in the quest for even better techniques for identifying women at risk from this dreaded disease.

The assessment of diagnostic performance is relatively straightforward in breast screening where a final diagnosis (cancer or no cancer) is definitively established. Many workers have pointed out how difficult this becomes when the diagnosis is elusive and the patient may not necessarily undergo early biopsy or surgery – viz magnetic resonance imaging (MRI) in the diagnosis of multiple sclerosis[7]. Even for something relatively straightforward such as MR of the knee, the fact that only a selection of patients undergo arthroscopy hinders the assessment of diagnostic performance[8].

Diagnostic impact

If a new technique successfully passes through the above two stages of assessment, it should be possible to prove that it helps make an impact on the clinician's diagnosis, either by providing a new, unexpected diagnosis or by improving the clinician's confidence in their working clinical diagnosis. Such information is extremely difficult to obtain unless the confidence in the working diagnosis is established before the first imaging investigation. Historically, diagnostic confidence information has been obtained in patients who were referred for VQ scintigrams for possible pulmonary embolus (PE) where the *a priori* clinical probability was necessary in order to provide a definitive report. This made it relatively simple to compare and prove the beneficial diagnostic impact of computed tomography (CT) pulmonary angiography[9] and has led to general acceptance in the UK that nuclear medicine (NM) referrals for possible PE should now be limited to those patients with a relatively normal chest radiograph, with all other patients directed towards CT.

Relatively few clinicians state their possible differential diagnosis in general referrals for imaging examinations, let alone their confidence in the leading diagnosis. Only when this information is demanded at the outset can the true diagnostic impact of a new investigation be measured. Some might argue that all imaging is aimed at reducing diagnostic uncertainty[10] and that any investigation which improves diagnostic confidence is a 'good thing'. But an investigation which merely confirms the clinician's diagnosis may be an unnecessary luxury. Alternatively, an investigation which completely alters the clinician's diagnosis (say from benign disease to probable cancer) may completely change the patient's clinical course – and save the clinician the embarrassment of going up the wrong diagnostic alley. And such changes in diagnosis (diagnostic impact) must be measured as radiologists and clinicians need to justify the considerable expense of diagnostic certainty.

Therapeutic impact

Now that the investigation under scrutiny has passed the first three levels of the technology assessment hierarchy, it must be shown to have therapeutic value. If, after an investigation has been performed, the clinician ends up doing what he or she would have done anyway, it could be argued that the test was unnecessary. In the days when radiologists had to scrutinise requests assiduously to avoid too many referrals and a departmental overspend, they frequently asked 'will the result of this investigation change your management?'. Indeed, this is still a very valid question, particularly when radiation exposure is at stake[11,12]. Again, clinicians must be encouraged to state before an investigation details about their proposed management; and they must also be asked what their management will be once the result of the investigation is apparent. Only by this method can the true therapeutic impact be measured. This can be achieved by means of a prospective observational study[13] but a purer study is where the new investigation is assessed alongside a conventional investigation on the same patient population by means of a randomised trial[14,15]. However, randomised trials are notoriously difficult to perform in diagnostic radiology and ethical review boards may refuse to sanction a study where one arm of patients is 'denied' access to the diagnostic test under scrutiny, no matter how new or experimental.

Impact on health

It should follow that any investigation of proven technical and diagnostic performance with positive clinical and therapeutic impact would be associated with a beneficial impact on health. But this may be difficult to prove: the side effects of surgery may mask the health gain in the immediate post-operative period and sometimes the diagnosis may have such an unfavourable outcome (for example, pancreatic cancer) that the beneficial influence of the diagnostic test is masked by the natural history of the disease. Even for benign disease, it is difficult to prove the benefit of high technology diagnosis in terms of improvement in quality of life[16]. It is much easier to prove the beneficial influence of interventional radiological techniques, where great advances have been made recently[17]. As a result, several surrogate markers have been used to assess impact of new techniques on health. Clearly, the avoidance of ionising radiation is one marker; and another may be the avoidance of potentially dangerous investigations. The use of MRI instead of Endoscopic Retrograde Cholangiopancreatography (ERCP) is one example; the development of fluid sensitive techniques allowed the introduction of MR cholangiopancreatography (MRCP)[18], which has virtually replaced diagnostic ERCP. Interestingly, this change in practice has come about with no full health technology assessment – merely common sense! In these days of patient choice, it may be that we should ask the patients which test they would prefer – all other information being equal; the presumed preference for MR over myelography was never formally assessed but can be assumed. However, the preference for MR over some other techniques may not be as apparent as expected; for example, not all patients prefer conventional MR of the shoulder over conventional arthrography – despite the perceived invasiveness of the latter[19].

Societal impact as a technology assessment measure

Because of the difficulties in proving the benefits of high technology investigations, health economists and others responsible for planning and purchasing healthcare have looked to yet other surrogates. Increasingly, health economists point out that the really expensive bits of healthcare relate to secondary care and in-patient stays. If it can be shown that the judicious use of imaging can make secondary care more efficient and shorten hospital admissions, then the case for the greater use and increased expenditure on imaging is made. And this is very much behind the recent UK NHS initiatives in providing increased access to imaging. Even with the recent expansion in imaging capacity, first on the back of various cancer initiatives and now from additional independent sector provision, the UK still performs far fewer CT and MR examinations than other developed nations. For example, the rate for CT examinations in the USA is now around 250 per 1000 of the population per annum; many times the rate in the UK. Numerous experts have tried to decide on the optimal level of provision for all such examinations, with scant evidence available. However, it is worth considering some of the societal benefits of increased imaging capacity which are now being addressed:

The patient. Patients do not like waiting for investigations and would prefer to avoid unnecessary and additional visits to clinics, hospitals, etc. So, if there is adequate capacity to offer an investigation (eg Chest CT) on the day of the clinic attendance, the patient is saved an unnecessary second visit for the diagnostic imaging required, and the whole investigation is cheaper – no bookings or letters, less car parking, etc. There is considerable evidence that MR is a better investigation for lumbar spine problems than plain radiography yet many patients are still referred for conventional lumbar spine radiographs[20]. Because of this a small number of patients suffer a delay in the diagnosis of serious disease (metastatic deposits, disc space infection, major disc herniation, etc). When multiplied, the cost of such delays in diagnosis may justify the increased expenditure.

The referring clinician. Only recently have clinicians started to accept that the objective findings of imaging are, in many situations, superior to their subjective clinical examination, even for something simple such as the presence or absence of an abdominal mass[14]. Furthermore, the newer generation of clinicians relies much more on the results of imaging to guide their management decisions and will frequently insist on high technology imaging before offering a final clinical diagnosis. Additionally, most modern clinicians prefer the newer investigations to the old[21]. Indeed, there is good evidence that modern imaging can optimise the surgical approach in many conditions, such as rectal carcinoma[22]. Such advantages need to be quantified in many more clinical situations. Interestingly, defence organisations have started to realise the importance of preoperative imaging and there are now some cases coming through where surgery is regarded as inappropriate in the light of the imaging findings (or the absence thereof).

The community. CT and MR were both developed at times when healthcare costs were under very close scrutiny and both came to be regarded (erroneously) as expensive investigations. Of course, when these machines could only handle one patient an hour they were expensive and many of the original cost-effectiveness studies were based on very high costs per procedure. However, both techniques can now offer very rapid, high volume functionality for most routine referrals. The costs of CT and MR are often lower than the alternatives they have replaced[23,24]. For example unenhanced CT of the abdomen is cheaper than even a short intravenous urogram (IVU); the cost of an MR of the lumbar spine pales into insignificance compared with the cost of a myelogram.

> **'If it can be shown that the judicious use of imaging can make secondary care more efficient and shorten hospital admissions, then the case for the greater use and increased expenditure on imaging is made.'**

But the real gain for high technology comes with reduced hospital admissions. It has been shown in numerous studies that early and judicious use of a single, high technology investigation can provide full diagnostic information (thereby avoiding a lengthy sequence of other tests) which, in turn, is related to shorter hospital stays[14,15]. Indeed, for abdominal conditions, a prompt CT examination may assist the emergency physician to decide not to admit the patient. Again, much work is still required to prove that overall costs can be reduced by increasing the availability of and access to appropriate imaging.

Conclusion

Radiologists, radiographers and others allied to imaging have, hitherto, been satisfied merely in showing the marvellous images produced by the increasingly sophisticated imaging devices now available and basking in the collective, reflected glory. Although these new techniques obviously assisted the referring clinician and often saved the patient more invasive tests, there has still been relatively little effort made to prove that they contribute to the totality of healthcare. Only by proving the effectiveness of pounds/dollars/euros spent on imaging will we be able to obtain the real and sustainable growth in imaging which many of us consider necessary. And, we will have to be on very firm ground, because increased expenditure on imaging will, almost certainly, mean cuts elsewhere.

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'Increased expenditure on imaging will mean cuts elsewhere.'

The future of radiology and the private healthcare sector

Tim Lewis

Introduction

The views expressed in this paper are garnered from considerable experience in the National Health Service (NHS) in the United Kingdom (UK) as a consultant radiologist and clinical director in a large tertiary referral NHS trust, and from being a member of a limited liability partnership (LLP) for private practice and independently employed by an imaging company in the private sector. These views have also been coloured by working in both the state and the independent sector in Australia. Views expressed are personal and are not representative of any current or previous employer.

The British and the NHS

The British love the NHS. It represents a triumph of socialist medicine over the marketplace and has improved the health of the community, particularly the less affluent, immeasurably. But, even from the outset when it was created by Nye Bevan, it had to address conflicts with the medical establishment; these were overcome largely by 'stuffing their mouths with gold'. Bevan's success resulted in a universal healthcare system used by the vast majority of the British population, ensuring that they received healthcare 'free at the point of delivery' (or sort of, prescription and some other charges rather undermined that philosophy). This was possible in a large part because healthcare was not as expensive as it is now and treatment options for many diseases were very limited. However, the suggestion that the costs would reduce as the health of the community improved seems to have been hugely optimistic. Such naivety is not confined to the past, of course, and some of the more recent pronouncements on the funding of drugs and the healthcare service as a whole would also not stand up well to scrutiny. There is a fundamental dichotomy between what the nation wants from its health service and what it is prepared for the state to pay. Indeed, the major problem with healthcare in the UK is this imbalance, along with the 'sacred cow' status that has overtaken sensible thought on the future of the NHS. To cover up this imbalance, successive governments have introduced reviews and reorganisations of the service as substitutes for expensive action. The hidden cost of these changes is a considerable drain on the service, both in terms of actual costs of the reorganisation (often not known) and the consequent disruption and loss of confidence by those who provide the service. And, the usual end result is a return to the status quo of a few re-organisations previously.

Healthcare costs and controls

With time and research, western healthcare has become much more inclusive and vastly more expensive. Radiology is responsible for a large part of this through providing better but much more expensive diagnostics. The attempt to control healthcare spending by successive governments created a market for private diagnostics that introduced magnetic resonance imaging (MRI) particularly into mainstream clinical practice, filling the gap between public expectation and reality. The focus on patient expectations has resulted in a more patient friendly service and created competition. In turn, this competition has had the effect of relieving pressure on limited NHS services, so keeping NHS imaging departments afloat when funding was limited.

More recently, there have been dramatic changes in the way the government intends to deliver healthcare. A genuine competitive market, both within the private sector and between NHS hospitals has been introduced. Should anyone doubt this then they need only refer to the code of practice that has been established to support NHS hospitals to advertise.

Healthcare transformation?

At the same time as private healthcare providers have entered the market, the NHS has undergone a transformation of its information technology (IT) facilities, with all hospitals due to get picture archiving and communication systems (PACS), and a national electronic patient record being introduced. The challenges for radiology are to utilise these enhancements effectively while maintaining control of the patient pathway. These IT changes will also produce considerable challenges in the healthcare market.

It is also helpful to examine professional attitudes. When the NHS was first set up, it was to support the contract between the patient and his (or her) doctor that had existed since Hippocratic times. The patient, effectively, had a contract with the doctor to address his or her medical problems, a fact that is still reflected in the guidance from the General Medical Council (GMC). This expects every doctor to 'make the care of your patient your first concern'. The NHS, which provided the funding and equipment necessary, facilitated the delivery of this patient/doctor contract.

More recently, that contract has altered fundamentally. Advocates for the patient, the NHS Primary Care Trusts (PCT) have negotiated with service deliverers, predominantly the acute NHS Trusts, to treat patients. The patient's primary contract is with the family doctor who then negotiates with the secondary healthcare NHS trust to treat. The doctor in secondary care now becomes an agent for the NHS to deliver on its contract with the patient. The link between the patient and the doctor, often tenuous in the first place with regard to imaging in the NHS, has been completely broken. In reflecting this change, radiology examinations and reports have become more akin to 'cans of baked beans', to be contracted for nationally. It was this supermarket approach that resulted in the National Diagnostics Initiative waves 1 & 2 which, while achieving much in the short term, have raised as many questions and concerns as answers.

Radiologists: Parts in the healthcare machine

The most recent changes to healthcare delivery have resulted in the radiologist now being just another part of the healthcare 'machine'. An imaging department also requires clerical and administrative staff to receive the patient and handle the paperwork, technical staff to perform or assist with the examination, and radiologists to perform and/or interpret the studies. With skill-mix in the NHS, the technical/radiological relationship has become blurred for reasons as much to do with career enhancement and recruitment/retention of staff as to do with patient management. Imaging examinations can be divided into four groups:

- Non-invasive (no needle) imaging where the end point of the examination is clear; for example, a chest x-ray. More complex studies may also come into this group; for example, ultrasound, and computed tomography, or magnetic resonance imaging studies, where contrast agents are not required.
- Invasive studies where cover is needed from medically qualified staff; investigations involving the injection of iodinated contrast would fall into this category.
- Examinations that require expert input throughout; examples include angiography and interventional procedures.
- Studies that require expert interpretative skills above the general level such as functional magnetic resonance imaging (fMRI) examinations.

Many studies can be treated in isolation. So a chest radiograph with a request that reads 'shortness of breath, ? congestive cardiac failure' and is without previous history or images may be dealt with easily by any radiologist happy to interpret a chest x-ray. This interpretation can take place anywhere in the world, raising challenging questions about registration, insurance and reputation, along with standards of communication (not so much English but the language of radiological reports for use in the UK). Such reporting is not vulnerable to accusations that the interpreting radiologist does not know the referrer, or that he or she is not part of the clinical

> There is a dichotomy between what the nation wants and what it is prepared to pay.

team. In more complex studies these factors may be of more significance.
An imaging department is, however, about more than just getting the correct diagnosis. Not only must it issue accurate and timely reports but it should also have staff available for review of cases and discussion with clinicians. This requires expert staff within a department and, in consequence, requires sufficient expert staff for cover throughout, probably, the full 24/7 cycle. There is no possibility of moving functions that require direct interaction with patients but all others can be exported. And, on the basis of commercial management, this may well include consultant radiologists' posts.

Private radiology practice

Traditionally, private radiology has been a small player in the healthcare market. It has been organised on an individual patient basis with high cost/low volume metrics. Consultant radiologists that provide private radiology services have received a significant part of their income from a very small part of their work.
This arises from the original consultant contract where 'maximum part-time' consultants could trade a reduction of 10 per cent of their salary for the right to perform unlimited private practice in their own time. Often, too, there was no change in their NHS working times which, in any event, were very loose; notionally seven 3 hour sessions per week, plus on-call for non teaching hospital consultants.
This imbalance maintained high unit costs for private work, reducing the demand. It also ensured that consultants could maintain an income that they thought appropriate within a reasonable working week. It was not, however, a stable system and the introduction of government reforms and targets for imaging have, effectively, ended this approach. The outsourcing of imaging and reporting has had a dramatic change in the unit cost of tests but, possibly, not for the incomes of radiologists. However, what it has done is to achieve a more balanced market where reimbursement within the private sector is not far out of balance with public sector work.

Where does this leave the radiologist?

British radiology remains firmly attached to the district general and teaching hospitals of the NHS. The current medical staffing contract is interpreted as allowing for work outside the NHS contracted hours, subject to various limitations, not all of which have been tested in law. In addition to the requirement to offer an 11th work session to the employing NHS Trust, there may be restrictions imposed relating to both conflict of interest (working against the interests of the primary employer) and the European Working Time Directive. Some of these restrictions are imposed centrally by the Department of Health (England), such as the additionality clause of phase 1 of the National Diagnostics Initiative and the lack of clarity over additionality in phase 2.
Common sense will likely prevail over the boundaries of work but may take some time to emerge. It has been suggested, too, that NHS consultant radiologists working for a private healthcare or imaging organisation (or similar) that is seeking NHS contracts, may infringe on the conflict of interest rule.
While there is a confusing morass of different directives and interpretations, these will clear in time and lead to a much more open and fluid market for radiology. It is likely that the NHS, effectively the monopoly employer, will cease to have such control and that radiologists will see other markets for their skills. With the change in pension regulations coming in 2013, some of the attractiveness of the NHS as an employer for life (rather like the NHS providing a service from the cradle to the grave) will be lost. Radiologists will train within the state sector primarily but will then market their skills to the highest bidder.
The achievement of excellence in academic radiology spheres will require radiologists to remain within the state sector and the tertiary referral areas at present. but even this is likely to change with time.

Where is radiology going?

All of the above begs the question about where is radiology going. Radiology is at great risk of being lost in all but a few areas. In addition to the 'conventional' turf wars being fought out between different specialty groups; for example, cardiology v vascular intervention, the advances in imaging are making diagnostic images much easier to interpret, at least apparently. In the United States of America, neurologists have long since set up their own imaging centres, interpreting studies referred from themselves and there may well be a move to follow in these footsteps in the

> Reimbursement within the private sector is not far out of balance with public sector work.

> More questions are to be asked as to where the radiologist adds value.

UK. More and more questions are likely to be asked as to where the radiologist adds value to the process. The conventional answer that 'radiologists are the only group who **really** understand the images' will be lost in the commercial pressure for lower cost services, except in areas of enlightened management. PACS now allows images to be exported anywhere in the world. Much of radiology requires no understanding of the subtle nuances of referrers and can be done by any appropriately trained radiologist. It is likely that UK registration and registerable qualifications will be necessary, but these have not proved an impediment to the National Diagnostics Initiative phase 1 schemes. The major bar has been user unhappiness, often related to a different style of reporting, and this is easily overcome. In reality, the UK market has been opened up to international competition and those radiologists practising from low cost of living areas will be at an advantage.

Will skill mix have an impact? Skill mix has come in to help support career development for radiographers and save money for NHS Trusts. In many cases, the issues have not been thoroughly thought through and resolved, leaving partially trained staff with interpretative work to do. The question of why the NHS trains radiologists (five years at medical school and seven years postgraduate study), then gives the work to radiographers (three years training and a post graduate qualification of at least a year) has not been fully answered.

Probably the question that most needs to be answered is, 'What is the added value of the radiologist?' In some areas the answer is nothing at all: those parts of radiology that are amenable to pattern recognition do not require in depth knowledge of physiology and pathology to interpret appropriately.

In those cases, radiographer reporting seems eminently sensible. Indeed, it may even be superior to using a radiologist because it is cheaper and radiologists may get bored with pattern recognition level work and so make mistakes. It is noticeable, however, that private imaging networks have not fallen over themselves to use radiographers for reporting, and some market their reporting on quality grounds, using subspecialty radiologists to imply quality and attract more custom.

How, then do we move ahead? The division will be into those who perform studies on patients and those that don't. Those performing studies may well still have a turf battle to fight with other medical specialties but are unquestionably necessary for the patient's diagnosis. Interventionists should, therefore, be in a strong position and the move towards a much more hands on approach for radiology is necessary for its survival.

Subspecialties in radiology may also survive, but only by 'adding value'. In part, this will be by the extra specificity that a specialist radiologist can bring to a diagnosis but also by the 'rubber stamp' it endows and through which necessary medico-legal support will come. With increasing litigation in radiology, the interpretation by an expert will continue to carry weight, and this is likely to increase.

Radiologists will also gravitate towards formal partnerships, providing either specialist services or a whole range of services. These partnerships will then be marketed towards the NHS as well as directly to the public, resulting in a further outsourcing of NHS work.

For the remainder of radiology, it really is up for grabs. If 'image acquisition and reporting service providers' with lower overheads can compete on an item of service basis with radiologists, those service providers will get the work. In addition to cost, intending service providers will have to show rapid turn around for reports, probably of less than 10 minutes, to address the growing 'one stop' philosophy for patient management. They will be available at the beck and call of multiple different centres that will post images for whoever is employed to interpret them. Time will be money and maintenance of accreditation will be at the radiologist's (always supposing it is radiologists undertaking the work) own expense, and time off will mean income lost. Somewhat more positively, such developments may well provide support for web based learning and competency assessments.

Within private radiology practice, 'quality' providers will emerge and these will, probably, fare better than the average district general type hospital in terms of competing for referrals and service provision. But, as with the state sector, (which may disappear entirely except as an insurance based system of commissioning), much of the work will be allocated on the basis of cost and turnaround times.

And what of self-referrals for imaging? Organisations are setting up to provide 'MOT' like services to the worried well on the premise that whole body imaging will demonstrate lesions early enough to allow cure. As the medical profession is not perfect, there will always be a place for self referral, to investigate cases where salient clinical signs and symptoms are overlooked and/or ignored by clinicians. However, these represent a different group from the 'worried well' who think that medicine has an answer to everything. These self referrals for MOT-like services represent nothing less than the transfer of money from the anxious to the rich, something that should be condemned by all the medical profession. Such organisations are unlikely to have a major impact on the delivery of radiology, although they may well provide a 'useful' niche for some individuals.

Probity and morality

There is a theme threaded throughout this discussion which reflects on the morals and probity of the medical profession. In a time of rapid change, many opportunities will present themselves to those who are enterprising and energetic; these will be looked on as threats by those of a more nervous disposition. However, in choosing what to do and how to proceed, doctors must reflect the position that patients' interests should come first.

Different health maintenance organisations, including the NHS, now look on clinicians much more as employees, even vassals, charged with doing the greater good for the organisation. They forget that, for doctors, there is a higher authority. Those who place 'Dr' in front of their names, accept the need to reflect primarily on the best interest of their patients, not their employers. While this can be uncomfortable, doctors must make it clear to their employers, whatever their hue, that failure to reflect primarily on the needs of patients may well result in having to defend their actions before the GMC, which has the power not only to take away their livelihood, but also any chance of making a living as a doctor until such time as the sanction is lifted.

Conclusion

To be successful, radiologists have to add something, whether it is a personal touch to patients or the quality of their reports. There is little future for the generalist in a market dominated by the availability of specialist expertise. Personal contacts will not sway referrers as their patients become wiser over the expected value of a radiologist's report. To survive, radiologists will have to remember their professional obligations and accept that they are part of a service industry where quality is measurable in different ways but always allows for comparison.

Tim Lewis is a consultant radiologist from Bristol.

> 'A much more hands on approach for radiology is necessary for its survival.'

Modernisation and healthcare careers - help or hindrance?

Christine Jackson

Introduction

Service modernisation is a term which made its debut on the scene of radiography some 10 or more years since, and is used with increasing frequency by policy makers charged with visioning the National Health Service (NHS) to ensure the service remains fit for purpose.

Across the profession of radiography there are individuals and organisations that are embracing willingly the concept and impact of modernisation. It is also the case that there are radiographers who, perhaps, do not always share the modernist view point, or who feel that there are some aspects of modernisation which cause service/sector fragmentation. This article examines aspects of modernisation and its effect on academic and clinical integration through a particular career pathway – the clinical academic career route.

What is modernisation?

It is helpful, first, to determine what is meant by the term 'modernisation', and, subsequently, to look behind the meaning to understand the effects of modernisation programmes on clinical academic healthcare careers. Within a typical dictionary[1], two definitions for the term 'to modernise' may be found:

- To make modern; adapt to modern needs or habits.
- To adopt modern ways or views.

Consider the first explanation which states 'to make modern'. There is an implication here that there are *extrinsic* forces at work which compel us to use, not always willingly, modernisation as a process for change. Is this the way radiographers view modernisation – something which is imposed upon the profession as an extrinsic action?

Perhaps preferable is the second statement which defines modernisation as adapting to modern needs or habits, and adopting modern ways or views. These statements confer a degree of ownership and autonomy within the process. Within oncology services, it can be argued that staff and patients have an intrinsic drive towards modernism,

> 'Some aspects of modernisation which cause service/sector fragmentation.'

and that it does not always require policy imperatives to initiate modern practice or consolidate change.

The healthy approach would be to consider ‘modernisation’ as a continuum, with both extrinsic and intrinsic values within the continuum. Drivers of modernisation should always aim at getting a balance between these extrinsic and intrinsic factors, and getting the balance right is an important holistic philosophy for the profession and others. Modernisation should take account of the needs of the individual, of teams, the service and the professions as a whole. Too great an emphasis on extrinsically-led modernisation may reduce the levels of ownership and autonomy experienced by individuals and the professions within oncology services and this, in turn, can increase resistance to change. Ownership of and agreement to modernisation and change is an important maxim for any organisation and is more likely to bring compliance and satisfaction to the service. (See Figure 1.)

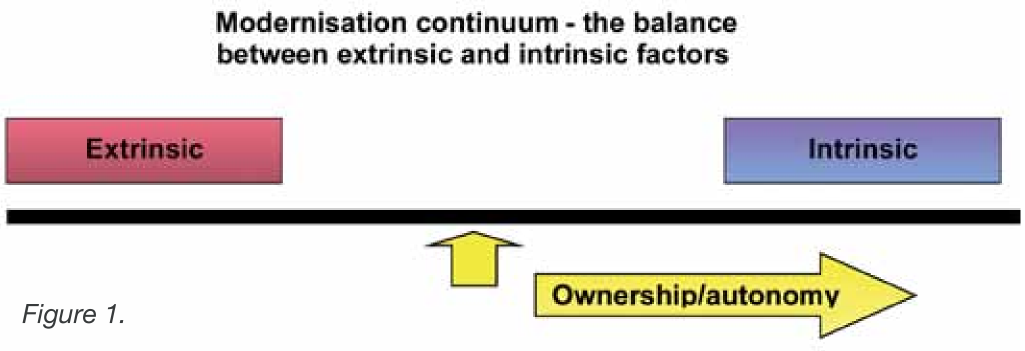


Figure 1.

There are a number of initiatives under the umbrella of modernisation in the NHS currently. The way in which some of these have impacted on the partnership between the clinical and academic sectors are discussed here.

Many of the key modernisation programmes have, with good reason, centred upon workforce and service redesign within the NHS. However, in the attempt to develop the NHS through modernisation initiatives, there is an increasing concern that the service and clinical staff are distancing themselves from academic colleagues in the higher education sector. This is problematic for those staff wishing to develop a career path that combines both clinical and academic elements of a healthcare profession.

Modernisation of academic radiography

Academic radiography was itself modernised in the early 1990s. A radical modernising process took place with the move of academic radiography from the NHS into higher education[2]. The change had considerable impact on the provision of academic radiography services for staff, students and schools of radiography. Becoming a graduate profession offered a broader platform of educational experiences and further career opportunities in teaching and research for academic radiographers, and exposed student radiographers to wider educational opportunities. Changes of this magnitude in terms of understanding the new environment and employment contracts, and the development of new undergraduate programmes presented academic staff with immediate and stressful challenges. Looking back at the period, and the uncertainties which modernisation of radiography education precipitated, many academic radiographers would agree that the modernisation continuum felt very much loaded towards an extrinsic focus, with a loss of individual autonomy much in evidence.

There were concerns, too, about the inevitable reduction of clinical-academic links exacerbated by geography and other factors. There were successes during this time (which have continued) as academic radiographers, supported

by clinical colleagues, educated successfully academics from other disciplines to the relevance of clinical practice. Clinical practice modules were given high priority, as was the assessment of competence within radiography degree programmes[3], and this has remained the case. Radiographers and other allied health professionals have changed attitudes in higher education towards assessment of clinical practice, a process of modernisation for higher education, therefore. This focus on clinical practice and assessment also encouraged clinical staff to play an increasing role in the development and delivery of undergraduate modules and, in the last decade, there has been a year on year increase in NHS staff engaging with higher education to access professional development programmes and higher level qualifications[4]. These encouraging landmarks were tempered however by criticisms of the approach to the content and delivery of undergraduate programmes. In particular, undergraduate programmes were accused of being overly academic, with an educational regime which left newly qualified staff insufficiently prepared for their first few months of work[5]. Notwithstanding the ensuing debates between academic and clinical staff on this subject, what is not in contention is the importance that all radiographers place on providing future generations of radiographers with the best possible undergraduate education. This is achieved through high quality academic and clinical practice, supported by research and a strong evidence base.

Although many benefits have been drawn from this relatively recent modernisation of radiography education, perhaps it has not provided the best platform for collaboration and integration between academic and clinical partners, and, hence, for development of clinical-academic career pathways. The placing of healthcare education in the higher education sector has affected the geographical location of training programmes; the contractual arrangements both for staff and programmes, and has highlighted differences in vision and goals between education institutions and service organisations. It is not surprising, therefore, that barriers to achieving effective partnerships for the benefit of staff and students in both clinical and academic settings remain. So, have the recent modernisation programmes aimed at improving service delivery within the NHS assisted with removing some of the barriers, or are they able to assist?

A common career framework for NHS staff?

The NHS now has the benefit of a new career structure following work completed in 2004 by the Modernisation Agency[6]. This depicts a nine level career framework for healthcare staff employed in the NHS in England. The framework provides a pathway for healthcare staff to engage in and develop professional expertise and expert practice through a supported and developmental structure. However, staff across many professions were disappointed to find that it did not take account of how academic staff might link across from higher education and work within the framework. In addition, the framework did not provide a mechanism for staff in clinical settings who might wish to engage more directly with the academic environment. It seems that modernisation in this context aligns more closely to the 'make modern' definition rather than 'adapting to modern needs' in that the framework fails to support that cadre of clinicians and academics who wish to work more closely together.

Skills for Health are about to complete a further project which contributes to the larger allied health professions modernising healthcare careers agenda[7]. This later project uses national workforce competences to assist in service redesign and to develop effective patient pathways. The competences have applications and uses which include workforce development but it remains to be seen whether this Skills for Health led modernisation of Allied Health Professions careers provides a sufficiently in-depth range of competences that take account of research, educational practice within the clinical setting, and partnership with the education sector. Research and education competences are an important component of continuing professional development for all radiographers across both the healthcare and the higher education sectors, and through the entire career pathway. Research and education competences provide a shared platform through which clinical and academic healthcare staff can work together to develop effective and mutually beneficial clinical-academic careers.

Modernising clinical-academic careers?

Modernisation has recently re-emerged for healthcare professions employed in the education sector. The Department of Health and the Department for Education and Skills have commissioned a number of key reports in the last few years that have sought to offer support for those wishing to pursue clinical-academic careers. This series of reports[8-10] has identified the need for flexible career pathways which enhance the working partnerships between academic and clinical settings for all healthcare professionals through for example, joint appointments, facilitative contractual arrangements, knowledge transfer and research collaboration.

Many academic staff wish to pursue careers in which they have opportunities to re-engage with clinical practice through clinically based research, or through the regaining of clinical skills using effective joint contractual arrangements. Equally, those clinical staff wishing to advance their careers as specialist practitioners or clinical researchers, for example, often require academic support through higher professional or research qualifications and professional development programmes.

A model for modernising clinical-academic careers

It is possible to offer a model of modernisation that would assist those wishing to pursue clinical-academic careers and that incorporates clinical, teaching and research strands. The United Kingdom Clinical Research Collaboration (UKCRC) intends to develop a model which supports clinical-academic careers in nursing and allied health professions[11]. The report produced by the UKCRC supports the view of many clinical and academic healthcare staff in nursing and allied health professions by placing the clinical strand firmly at the centre of career development. The proposals include the provision of appropriate infrastructure support including protected funding (see Figure 2), professional training, flexible employment contracts, support for higher qualifications and mentoring.

The model also offers the possibility of following a clinical-academic career successfully from early career positions through to leadership positions across both clinical and education sectors. The model encourages portfolio career development with sessional employment, secondments and sabbaticals between the sectors. (See Figure 3.)

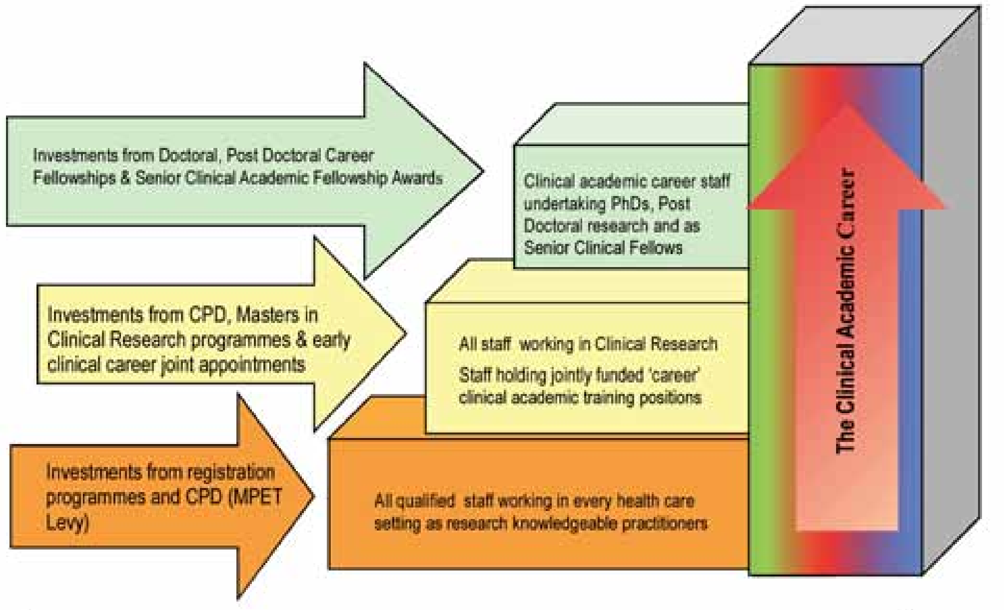
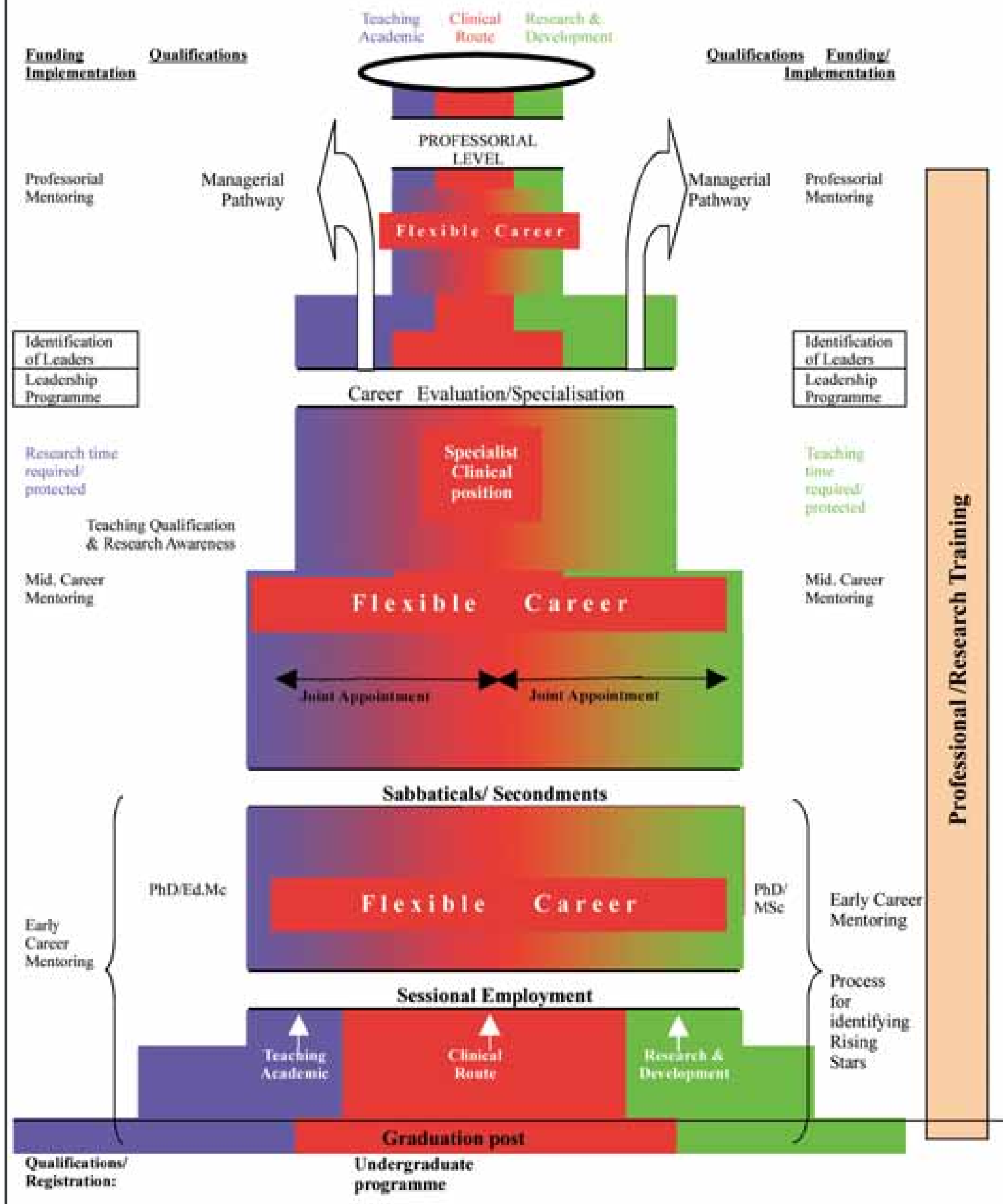


Figure 2 – Investments in a clinical academic career pathway for health care staff

Figure 3

Proposed model for developing Clinical Academic Careers



> Room for cautious optimism for those radiographers wishing to develop an effective and supported clinical-academic career.

Conclusion

There is room for cautious optimism for those radiographers wishing to develop an effective and supported clinical-academic career, particularly if the UKCRC model is taken up on a widespread basis. Nevertheless, this alone may be insufficient and it is essential that future modernisation programmes are scrutinised very carefully to ensure that their underpinning philosophies, directions and modelling are able to support an inclusive clinical-academic partnership. This will bring benefits to services and patients as well as to staff and students. It will also demonstrate very clearly a balance between the extrinsic and intrinsic values of modernisation.

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Radiotherapy training tools for yesterday's future

Andrew W Beavis, Roger Phillips and James W Ward

Infinite resources?

Radiotherapy techniques have evolved rapidly in recent years. Between the mid-1990s and the beginning of this century, most of the developments took place in large academic facilities and initial implementation of new techniques was limited to such centres. However, the advent of commercial treatment planning systems and treatment delivery machines has, essentially, made novel treatment modalities available to any hospital that can afford the equipment. In the United Kingdom (UK) a Department of Health initiative led to a government funded scheme to replace old and purchase additional treatment machines, at least partially with the intention of promoting the implementation of new, exciting techniques. Unfortunately, the uptake and clinical implementation of novel techniques, such as intensity modulated radiotherapy (IMRT), was slower than was initially anticipated. One of the reasons often given for this is a lack of resources and 'machine time' for training and education.

On UK training courses, therapeutic radiography students have the opportunity to augment their classroom, theoretical learning with experience gained in their host clinical departments. Although these course providers strive to provide them with the best environments possible and give them the benefit of collectively acquired experience, students cannot benefit from a fundamental aspect of the learning process, namely practice, practice, practice; the demands placed on resources in the clinic to provide the necessary volume of treatments and to keep waiting lists down mean that there is not the luxury of 'spare machines' for students' use.

Another educational philosophy generally applied outside of medicine, is to allow the 'learner' to learn by making mistakes; or, more exactly, to develop knowledge whilst seeking to prevent mistakes made previously. It is not difficult to understand why, traditionally, it is not desirable to allow learning via this methodology in radiotherapy.

> Students cannot benefit from a fundamental aspect of the learning process – practice, practice, practice.

Virtual reality

A solution to each of the problems discussed above is to introduce virtual reality (VR) training tools. A VR training platform that allows students to learn about the features of the treatment machine, to practice setting a patient up and to learn an appreciation of the required accuracy of treatment would, clearly, be a useful tool. If a student or a group of students could use such a tool to practice simple and complex patient set ups as many times as it takes 'to get it right' the potential value of a VR approach increases. Finally, a system that allows no damage to be suffered to the treatment unit or the patient no matter what the student attempts, sensible or otherwise, will add value to students' experiences because they will not feel inhibited in what they try.

The VERT project

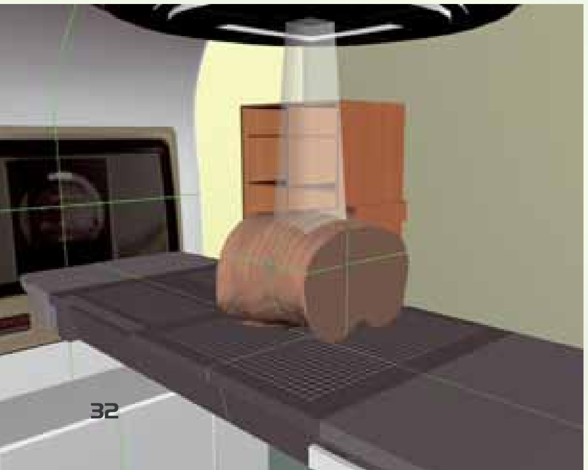
In our work we have created a virtual reality platform for such training, the Virtual Environment for Radiotherapy Training (VERT). This platform uses immersive visualization technology and software, developed in-house, to create a 'virtual reality' training simulator which is similar to flight simulators well known in the aviation industry. A virtual treatment room containing a linear accelerator (linac) was created[1] as a solution to address the lack of access to clinical equipment that students face. The group that has developed this work is a multi-disciplinary collaboration: a clinical radiotherapy physicist (Beavis) who has a track record of implementing new clinical technologies/techniques such as IMRT, and has a keen interest in education; a research professor in computer science (Phillips) with a broad track record that includes innovative medical applications and technology transfer to industry, and a computer science research fellow (Ward) with specific expertise in computer graphics and virtual reality, and their application. Additional support has been provided by the teaching faculty at Sheffield Hallam University via their radiotherapy training school. This input from the school has ensured that the VERT work remains valid and relevant to students and their learning needs.

Our virtual models of the treatment room and linac are accurate to within 2mm, and are based on a real clinical bunker at Princess Royal Hospital, Hull.

VR treatment room and linac, based on a clinical unit at Princess Royal Hospital, Hull, and accurate to within 2mm.

We decided to keep the details of the treatment room and linac faithful to reality so that the training platform had the precise look and feel of a typical treatment room situation. This aspect of building VR simulations is very important indeed, and considered to be key to achieving success in ‘convincing’ users that they are using a surrogate for reality. The linac itself has all the movements and major functionality of its real world counterpart. One functionality that cannot be copied is the radiation production, although the virtual model does have both a light field and a visual simulation of the radiation beam. In summary, the gantry and collimator of the virtual machine can be rotated as would be expected; the couch can be driven up/down, laterally, in/out and rotated, and room lights and targeting lasers can be switched on and off, as can the light-field.

VR linac with ‘patient’ in situ and showing the targeting lasers.



Additional features are included that are not available in the real world; for example, a collision detection algorithm monitors the motion of the machine and, when a collision between the couch and gantry is imminent, causes the linac to glow a warning red colour[2].

VR linac glowing red as gantry and couch in imminent danger of collision.

Adding the patient

Of course, learning to drive the linac is only part of the skills that student radiographers must acquire. More importantly, they must become proficient in the setting up of patients for treatment. To this end and to enable the demonstration of treatment plans, computed tomography (CT) based plans from our CMS treatment planning system have been implemented into VERT[1]. From the data (contours) available from the treatment planning system a three dimensional (3-D) model of the patient, which includes all the contoured organs and the skin surface, is placed on the couch. The CT data is also available to be shown as individual slices with the window/level and slice location being controlled via simple slider bars. The beams defined in the treatment plan can be displayed, both conventional and IMRT. Isodose clouds can be added provided that the dose distribution was computed in the planning system. Since, typically, only the region around the treatment volume is scanned we have also created a full body patient for some applications. The patient is positioned on the treatment couch and is correctly placed with respect to the machine’s isocentre. For training purposes, we have a limited set of anonymous, specially developed, plans. However, any plan from our clinical library can be loaded so making the tool useful for continuing professional development (CPD) activity, or for the development of new techniques in the clinic. When the patient is included in the scene, the collision detection algorithm will account for this, too, and issue warnings when the patient is in danger.

Disneyland for radiotherapy?

The software component of VERT is designed such that it can run on a variety of different graphics platforms. These include regular personal computer (PC) monitors, and projector systems such as those found in seminar rooms in most hospitals and teaching facilities. However, these ‘visualization platforms’ are generally smaller than the standard linac. If the VR system is to be used as a truly viable alternative to training on a real machine, then it is desirable to make the projection at ‘life-size’.
At the Hull Immersive Visualization Environment (HIVE), located at the

‘The projection system interfaces with the user’s brain to make the scene appear to be fully 3-D.’

University of Hull, we are able to display the projection of the treatment room on the Powerwall, which is a 5.3m x 2.5m back projected screen. The projection equipment is of sufficient resolution to project high quality images at this scale. It also caters for 3D-stereoscopic visualization, the type of technology now very familiar in theme-parks. Via 3-D glasses the computer/projection system interfaces with the user's brain to make the projected scene appear to be fully 3-D. This is not as sinister as it may seem. The projector provides left and right eye images in sequence at 50 images per eye per second. The glasses serve to shut off the 'opposite' eye when each image is generated. The 'left' and 'right' eye images are slightly offset from each other and this is sufficient to 'fool' the brain so that a 3-D scene is perceived. The term 'immersive visualization' portrays the intention to immerse the user in the virtual reality scene. The greater the sense of immersion, the more realistic the scene or, in this case, the more real the training platform appears to be to the users. The more realistic the experience is made, the more useful the training platform becomes.
The back projected, large scale hardware platform is desirable for class based activity. The tutor can walk about in front of the screen without 'blocking' the projected image. We believe that this kind of system will be useful and, indeed, within a few years, present in all higher education facilities as an integrated part of the teaching resources. Its cost may prove to be too great to expect to have this sort of platform in hospital seminar rooms to use in staff training, technique development, or CPD. However, we have also implemented VERT on a cheaper, forward projected platform which uses dual projectors equipped with polarising filters and a polarising preserving screen. The associated 3-D glasses are cheaper and are also available in a disposable form. The complete cost of the forward projection system is approximately 10 per cent of the fully immersive system and will fit easily within a typical hospital seminar room. In Hull, we also have a transportable system that can be taken to almost any location although a transit van is required to transport the screen. The software will also run on 3-D enabled computer monitors and we have implemented a number of these. However, the benefit to be gained by the use of 3-D visualisation on this smaller scale still remains to be proven, although work is ongoing to explore its worth in treatment planning[3].

More hooks to the real world

Similarly to wanting to make the virtual linac and bunker **look** as real as possible in order to promote a sense of reality, it was deemed important that the control device should also provide a close link to reality. It was decided to utilise an authentic hand pendant from the clinic rather than utilising a 'game pad' or leaving the control to a second user sat at the PC keyboard. In the real treatment room, the radiographer would expect to have control over the machine and, indeed, the room environment, from the hand pendant. Consequently, the pendant was integrated to our software, linking its buttons and thumb wheels to the expected motions and functions of the linac[4].

Head tracking

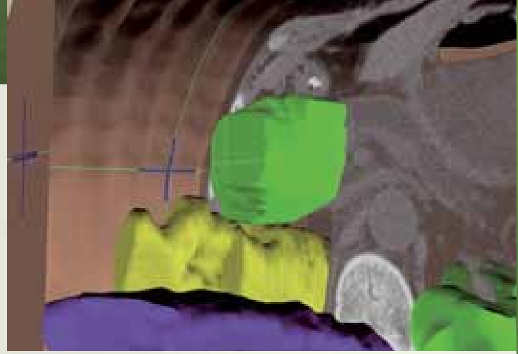
Positional tracking of the observer is also available in HIVE. This employs a system of computer controlled cameras positioned around the screen area which 'track' the position of reflective markers. One set of glasses has been adapted to have these markers attached and this results in the tracking computer being able to calculate the viewing position of the wearer. This information is fed to the computer generating the 3-D scene (ie the linac bunker) and allows it to create a view of the virtual linac bunker which is correct both for the observer's position and for the direction of gaze. This allows the user to 'walk around' an object, viewing it from different aspects. As a result, the trainee can view the patient from the left side of the patient, at the patient's head or foot, then walk round to the right side of the patient. If the gantry was in a 'lateral beam' position, the user could even position themselves between the gantry and couch. In fact, a trainee can literally move around the patient and

> 'A trainee can move around the patient and the machine in the same way he or she would move about in the real room.'

the machine in the virtual world in the same way he or she would move about in the real room.

Applications of the software for basic training

Having developed a description of our training platform, it is useful to explore how it might be used in the training centre and in the clinic. Following discussions with colleagues in our training centre and with the practice development facilitator at Princess Royal Hospital, we developed a lesson plan for a group of first year therapeutic radiography students and trainee assistant practitioners in radiotherapy. The aim was to develop an understanding of why accuracy of set-up is so important and, to achieve this, we discussed and demonstrated the concept of the mechanical isocentre, set-up lasers, target volumes and the generation of conformal dose volumes. A patient data set from the treatment planning system was slightly altered by adding visible set-up crosses to the skin surface. The students and trainees were then taken to HIVE to use the full scale VERT. The concept of the linac mechanical isocentre was demonstrated via the use of a virtual front pointer. Additionally, a set of Cartesian (x,y,z) coordinate axes, whose origin sat at the isocentre, were added to the scene. When the gantry or collimator was rotated, the virtual front pointer would rotate about their origin so emphasising the rotation about a single point. Similarly, the couch was positioned such that the front pointer 'touched' a clearly identifiable part of its 'tennis racket' top to demonstrate the rotation of the couch about the isocentre. To demonstrate setting up a patient, the virtual patient (with the modified skin surface) was added into the scene, with the couch lowered to the floor. Following the same procedure as would be followed in the clinic, the room lasers were switched on and, via the hand control pendant, the couch/patient was raised. The position of the couch was altered until the set-up crosses drawn on the patient's skin lined up with the lasers. Up to this point in the exercise, VERT is simply being used as a convenient alternative to the clinic resource, leaving the latter free for treating patients. However, a key point to understand is that the virtual world can offer enhancements to the experience available in the clinical setting. The next step in the demonstration was to 'fly' inside the patient, passing through the skin surface and looking at the position of the planning target volume (PTV) and other organs relative to the isocentre. This is generally difficult to achieve with a real patient! The position of the isocentre is demonstrated by the projection of the laser lines both inside the body and onto the inside surface of the skin. It is also enhanced by adding either the virtual front pointer or the coordinate axes. This demonstration was followed by a discussion linking the simulation process, the planning and the subsequent marking up of the patient's skin. Finally, to clearly demonstrate and discuss the importance of accuracy of set-up, objects from the treatment plan were added into the scene. A representation of each of the beams showed the coverage of the PTV and exclusion of the organs. The '95%' dose cloud was added to the scene. Doses are locked to the isocentre and the patient is locked to the couch; this allows the user to move the patient slightly and view the resulting 'mis-irradiation' of the tumour volume. VERT provides a 'set-up error' feature that makes this exercise easier. Feedback given by the students and trainees was very positive, and highlighted that such a graphic demonstration of the whole process as well as each stage of the process was invaluable in improving their understanding. Following the various different pilot studies, and comments from many visitors from training schools (including international visitors) and professional bodies, we have consistent feedback that the ability to practice any exercise without the fear of damaging machine or patient and being able to do so without the pressure of someone 'watching over your shoulder and the clock', is invaluable.



Looking inside the patient the position of the PTV (in the centre of the picture) can be seen in relation to proximal organs and the set-up crosses and lasers.

Other applications for the VR linac

Complex clinical techniques such as 'direct electron field ' or 'skin apposition' set-ups are universally considered

'Fly' inside the patient, pass through the skin surface and look at the position of the planning target volume.

> Engaging the 'play station' generation in discussions about radiotherapy and even physics.

to be tricky to master and can take some time even by experienced staff. With colleagues from Sheffield Hallam University, a pilot study was developed, creating a 'flight simulator' trainer for that purpose. This work is published[5] elsewhere but, in summary, a full bodied patient was given a number of different clinical mark ups for electron fields on the breast and thorax. A tutor led session first familiarised students with the problem and VERT, then group exercises allowed them to learn how to set up a patient for a direct field. Finally, each student was individually tested using a particular (reserved) mark up on the breast.

By now it should be clear how the system could be used for CPD activity within hospital departments. It also has a role in the development of new local processes for techniques such as image guided radiotherapy (IGRT). Staff in Hull have commented on how useful this training tool would have been when developing our IMRT processes at the turn of the century. Indeed, teaching 'slides' generated from the graphics of VERT have proven very popular in IMRT teaching seminars staged round the world.

Finally, we have taken the transportable version to school careers fairs and it has proven extremely valuable in engaging the 'play station' generation in discussions about radiotherapy and even physics!

Other virtual reality training tools

We have also developed anatomy training tools. In collaboration with faculty at Sheffield Hallam University, we are developing evaluation tests for our neuro-anatomy training system. These include randomised studies to assess the educational benefit of the use of virtual reality. The system provides a 3-D model of a human brain with which the user interacts via a 'tracked' hand held control device. This immersive device can be used to rotate the brain to choose the viewing angle and to select specific segments. When a segment is selected, it is highlighted and some recorded speech is replayed through the audio system and written information is projected on the Powerwall. Alternatively, segments can be selected from a bank of virtual buttons, activated via the hand set control. To facilitate studies of the learning style preferences of users of the system, a 'big brother' system was added which records and timestamps each user interaction event with the system.

Current developments

Development of VERT continues. We have created a consortium of interested and active teaching schools to help expand our outlook and the scope of the training platform. Specific current developments include the use of DICOM standards to read plans from the variety of treatment planning systems available to the community, and tools to enable training for IGRT.

Conclusion

We have implemented and started to evaluate a virtual reality training platform to complement experiences gained in the clinic. We continue to develop our work in this exciting and interesting area; it is a fertile ground for research in radiotherapy, teaching methodologies and computer science.

Thanks and appreciation

The authors would like to give thanks to the host of radiographers from our clinic (specifically Anne Jessop), Sheffield Hallam University (specifically Angela Duxbury, Rob Appleyard and Pete Bridge), and the numerous and frequent visitors to HIVE who have given us valuable advice to ensure our efforts remain valid and useful.

Andy Beavis is a consultant physicist at the Princess Royal Hospital, Hull. He is also a (honorary) senior research fellow at the University of Hull and visiting professor at Sheffield-Hallam University. Professor Roger Phillips is a research professor and James Ward is a research fellow, both at the University of Hull.

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Accurate patient positioning and gating in radiotherapy

David Landau

Introduction

Patient positioning is clearly a central part of the radiotherapy process. As radiotherapy technology generally has advanced, so too has the art and science of patient positioning. Until recently, it was sufficient to ink the field margins onto the patient and tattoo various skin positions. In certain situations, immobilization devices were used for improved reproducibility but the emphasis was still on getting the patient position aligned in relation to the radiotherapy unit as guided by skin-based anatomy. Contemporary techniques concentrate instead on trying to align the target volume to the radiotherapy unit. Guidance might include skin-based anatomy but is also sought from internal anatomical landmarks. Similarly, alignment of predefined landmarks was previously performed by eye. Modern systems rely equally, or sometimes entirely, on image registration technology and automated calculation of comparisons to reference images and settings.

In this article, it is not intended to give a detailed review of all available positioning and gating technologies, neither is it intended to review the basic rules of patient setup. Rather, it is intended to give a perspective of patient positioning in the context of recent advances in radiotherapy technology. This is a radiation oncologist's perspective and not that of a therapeutic radiographer or medical physicist. Of these three disciplines, the oncologist is the one furthest removed from the frontline activity of patient positioning and gating. Nevertheless, it is anticipated that the ideas expressed will not be too foreign to members of the other two disciplines.

Getting up to date

What are the technological advances that have impacted on radiotherapy delivery and thereby driven change in patient positioning? They are many and varied but the most important are in imaging and in radiotherapy planning.

Imaging

Three dimensional imaging has changed radically over the last decade. Computed tomography (CT) scanning now produces fine cut, high resolution images in a very short acquisition time. This technology is available in diagnostics units in every district general type hospital (DGH) in the United Kingdom (oddly, and by comaprison, CT simulators have lagged behind in many of the UK's radiotherapy centres). Instant cross sectional images and three dimensional (3-D) reconstructions allow precision localisation of primary tumours, enlarged lymph nodes and oligometastases.

Magnetic resonance imaging (MRI), too, is now also available in nearly all DGHs and provides superior soft-tissue definition compared to CT. This allows target volumes to defined more precisely than ever before. An obvious example is the identification of various crucial parts of the prostate target volume, including the apex, seminal vesicle and capsular invasion by tumour.

Positron emission tomography (PET) scanning can provide further functional definition to CT findings, again enabling further optimisation of radiotherapy target volumes. An example here is that of mediastinal lymph nodes for irradiation alongside primary non-small cell lung cancers. MRI, too, is now being developed for functional imaging.

The science of image registration has progressed alongside these multimodality imaging developments. This has relevance beyond target volume definition in the integration of new imaging systems into the treatment verification process. In relation to target definition, the availability of commercial image registration algorithms means that the benefits described above can be combined for each patient with accurate co-localisation of the different types of scan to inform decision making.

Finally, four dimensional (4-D) imaging refers to the ability to image over time, using two dimensional or 3-D images. This relies in part on image registration advances and has allowed study into how target volumes can move with time. This is discussed in a little more detail when gating is discussed separately, later in this article.

All of these imaging developments facilitate the increasingly accurate definition of the tumour target volume. Many of the advantages of this accuracy would be lost if this target volume could not be localized equally accurately by the radiotherapy unit. Furthermore, the localisation of the target volume by means of this multimodality imaging is not routinely referenced to any skin-based anatomy. Rather, it is referenced to a series of 3-D (x, y, z) co-ordinates within the patient and the imaging space. Ideally, therefore, the new patient positioning techniques need to refer to the same system of coordinates. This, clearly, puts skin tattoos into a rather outmoded context.

Radiotherapy planning

The ability to accurately define the tumour target volume would not, in itself, define a need for more accurate patient positioning if the radiotherapy unit was not able to target the high-dose radiotherapy to the volume accurately even when pointed at the right bit of the patient.

All radiotherapy centres should now be routinely planning radical radiotherapy treatments with 3-D planning systems, based on 3-D anatomical data from CT scanning. This allows treatment field directions, volumes and shapes to be optimized to ensure full coverage of the target volume. The beam weightings and wedges can be calculated for individual patients.

Intensity modulated radiotherapy (IMRT) is a further and major refinement of the conformal radiotherapy process. The introduction of wedges into the beam path modifies the intensity in a smooth manner across the field, with

'A perspective of patient positioning in context of recent advances in technology.'

> "A new definition of patient positioning, as follows – the positioning of the target volume relative to the radiotherapy unit."

a higher intensity at the thin end of the wedge. The IMRT process, powered by some almost magical mathematical modeling, results in the delivery of beams whose intensity over each square centimeter (or smaller with narrower multi-leaf collimators (MLC)) can vary almost independently. The ability to target complex volumes accurately is greatly enhanced and many published papers have demonstrated the improved therapeutic ratio of IMRT compared with standard conformal therapy.

As a result of these advances the drivers for the need to improve patient positioning can be summarized as follows:

- Increased accuracy of tumour target volume localization;
- Increased accuracy of target volume definition;
- Increased accuracy of target volume coverage;
- Increased awareness of target volume motion;
- The need to reference the target volume rather than the skin to the linear accelerator; and
- Technological advances in potential modalities for use in patient positioning.

What has resulted is a new definition of patient positioning, as follows:

- The positioning of the **target volume** relative to the radiotherapy unit by adjusting patient position.

Image guided radiotherapy

Many new systems of radiotherapy delivery have advanced patient positioning at their heart. Inevitably, the patient positioning process overlaps with other processes and the boundaries of the new patient positioning process are less clear cut. In the old world, the patient would be set up by skin marks and then treated. In the new world, this initial setup is either the start of a process or is entirely superfluous.

At its simplest, verification exercises that are not directly part of the positioning process are used to inform subsequent positioning episodes, for example, portal imaging. Such exercises work by changing setup instructions or tolerances. The verification process has in this way overlapped with the positioning process And, at this stage, most of the patient positioning is by skin marks.

Taken a step further, online verification directly informs daily setup and, as such, is integral to the positioning process. Portal images based on bony anatomy have been found to be more accurate than skin tattoos but this method is still not setting the patient position according to target volume position, except for bony or para-bony targets. Portal imaging software now routinely includes image registration algorithms that automatically calculate the accuracy or otherwise of the setup.

If the online verification is, for example, by cone beam CT or by 2-D imaging of fiducial markers, then another level of sophistication is reached. At this point the setup is by direct reference to the target volume. The changes in patient position are designed to bring the accurately localized target volume of the day in line with the radiotherapy unit. This development is most of what image guided radiotherapy (IGRT) is all about. Other systems can achieve this, for example, daily ultrasound of the prostate to localise the prostate relative to pelvic structures. For tumours that do not move relative to bony anatomy, for example, the brain and head and neck, orthogonal x-ray images are sufficient to achieve knowledge of target volume position and IGRT is achieved. Image registration of the orthogonal images makes this a more elegant and accurate process. This system is available on new linear accelerators (linac) equipped with orthovoltage imaging systems, either on the linac head or in the linac room. According to the new definition of patient positioning above, patient positioning is what, in turn, defines IGRT.

Intrafraction motion

So far in this discussion, good patient positioning has been acheived only at the start of each radiotherapy fraction. Can the patient position be adjusted during treatment if necessary? Some of the systems described above do not lend themselves to intrafraction motion monitoring, cone beam CT and prostate ultrasound being prime examples. Orthogonal x-ray images can be used for this purpose with a number of conditions. First, the system must allow rapid enough analysis of the combined images to be useful (in the case of the Cyberknife™ this is partly achieved by the long treatment time). The system setup should also allow for the images to be taken without altering either the couch position or, ideally, the gantry angle. The various sources of intrafraction motion also need to be considered. Patient movement could be monitored by real time skin contour visualisation. This is available through a new UK system, AlignRT™. This consists of a digital video device that can, in real time, compare the current skin surface to a reference taken at simulation, or at daily patient setup. The radiographers running the linac are informed if the patient moves outside of

> According to its new definition, patient positioning defines IGRT.

> Respiratory correction is not satisfactorily addressed with current systems.

predefined tolerances within a specified region of interest. For Cyberknife-based radiotherapy, patient movement is monitored by regular orthogonal x-ray images with registration. Despite the length of the hypofractionated treatment and the often fairly flimsy immobilization devices, these regular, intrafraction, 3-D verifications make this one of the most accurate linacs available at present. Strictly speaking, this is not a patient positioning system because the linac is moved relative to the patient, and not the other way around as with a conventional linac. The concept, however, remains constant and, in fact, on the latest model, the couch moves too.
Internal motion is of varying types. A prostate, for example, moves with bladder and rectal filling which is mostly unpredictable and highly variable. Internal imaging of the prostate in real time on a linac is highly problematic but, fortunately, the changes in position occur over a period of some minutes and the need for intrafraction verification is less acute. Respiratory motion, on the other hand, is certainly faster than this and so does interfere with patient positioning, according to the new definition of patient positioning.

Gating

Gating is simply one of the available means by which the alignment of the tumour target volume with the radiotherapy unit can be maintained despite respiratory motion of the same target volume relative to the radiotherapy unit. As such, it is simply an extension of the patient positioning process.
Potential solutions to overcoming patient position inaccuracies due to respiration include active breathing control, prolonged breath hold techniques and tumour tracking. To a greater or lesser extent all of these depend on the predictability and reproducibility of the respiratory cycle. For example, gating assumes that in a given phase of the respiratory cycle, to which the CT-simulator acquisition and the radiotherapy are gated, the target volume will always be in the same position within

the patient and relative to the linac. Whilst respiratory motion is more regular and predictable than rectal gas it is unfortunately still not as smooth as we would like. Training patients to breath to a pattern can help reproducibility in some cases. For many patients, however, these techniques prove too invasive. For others, the gain is minimal as the increase in accuracy of position of target volume relative to linac is not sufficient to allow significant margin reduction.

The Cyberknife™ system has a predictive model that is generated each day from the patient's own respiratory pattern to predict tumour position in real time. The real time data is acquired from monitoring a few points on the skin surface. This does not directly monitor tumour position, however, as it is well established that the chest wall and tumour can, to a degree, move independently of each other. The data is therefore regularly updated by orthogonal x-ray images of the tumour, with fiducial markers if required, providing actual tumour position information. The time taken to register and analyse the orthogonal images is, however, too long for real time use (>1 second). As a consequence, the information is only used to continually update the predictive model for that day's breathing pattern. In this manner the linac head and couch top are continually adjusted to track the tumour motion.

Finally, respiratory motion at the time of CT acquisition can result in systematic errors. If, for example, the anterior permanent marker (PM) is caught on the scan at an extreme point of inhale that is never reproduced during treatment, the mean position of the same PM during treatment could be a centimeter or more away from that seen on the CT. The AlignRT system can account for this by taking a series of images at both simulation and treatment. The maximum exhale images are automatically chosen for comparison, excluding much of the respiratory motion in this section of the patient positioning process.

Overall, the area of respiratory correction is not satisfactorily addressed with currently available systems and caution must be adopted when introducing new systems before margin reduction is attempted.

Conclusion

Patient positioning is an aspect of radiotherapy that is constantly changing with technological advances. This review provides an insight into a clinician's thoughts about what patient positioning means today. It is evident that the term 'patient positioning' is now inappropriate. The time has come for it to be replaced with something better, or dropped completely.

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Recent advances in radiation oncology: Are we hitting the target?

Anna Kirby and Jane Dobbs

Introduction

To realise fully the benefits of recent developments in methods of precisely shaping radiation fields to target volume, we must be sure that

- The target volume has been correctly defined; and
- That target volume is receiving the intended radiation dose during each and every fraction of the treatment course.

Recent advances in image guided radiotherapy (IGRT) have begun to address these issues. In this article, we review the definition, role, techniques, benefits and limitations of IGRT to date.

Background

Conformal and intensity-modulated radiotherapy (IMRT) enable tight shaping of high-dose radiation to target volume alongside reduced dose to adjacent normal tissues. IMRT, in particular, is associated with steep fall-off in dose outside the target volume such that accuracy is required in initial target delineation, localisation of the target during treatment, and minimisation of geometric uncertainties including set-up error and internal organ motion.

If the target volume in relation to the high-dose field can be accurately delineated, localised and stabilised, the dose to target can be safely escalated (enhancing local control) with little increase in the incidence of normal-tissue toxicity, as has been achieved in prostate cancer[1]. The requirement for enhanced precision increases further as the number of fractions falls (hypofractionated radiotherapy) and as the biological dose increases. Imaging at the time of treatment is crucial to ensure that radiotherapy is delivered as intended.

Definition

Broadly speaking, the term image guided radiotherapy (IGRT) can refer to use of imaging modalities in any aspect of the radiotherapy planning process including:

- Definition of gross tumour volume (GTV) or tissue at risk of microscopic spread of tumour (clinical target volume, CTV);
- Verification of target volume and/or normal tissue positioning prior to delivery of radiation; and
- Monitoring of inter- and intra-fraction movement of target, allowing daily adjustments of patient position.

Each of these will be considered in turn.

How can imaging be used to aid target volume definition?

Advances in imaging technologies have been driven by the need to increase their sensitivity, specificity, and accuracy in diagnostic settings. Gradually, as developments in radiotherapy planning software have allowed, such technologies have been translated into the setting of target volume definition. Until recently, most conformal radiotherapy planning has made use of computed tomography (CT) data. It is now possible to co-register data from other imaging technologies with that from CT such that target volumes can be delineated more accurately. Standard magnetic resonance imaging (MRI) can provide complementary information about the spatial extent of the tumour. Dynamic contrast-enhanced

MRI (DCE-MRI), blood oxygen-level dependent MRI (BOLD-MRI), magnetic resonance spectroscopy (MRS) and positron emission tomography (PET) can provide functional information, distinguishing sites of tumour activity from benign changes and, furthermore, identifying within tumours hypoxic sub-volumes that can represent areas of relative radio-resistance. DCE-MRI is a technique in which a paramagnetic low molecular weight contrast agent is injected intravenously and monitored, with multiple images over several minutes, as it enters tumour blood vessels and subsequently passes into the extracellular space. When contrast passes through the tumour capillary bed it is initially held in the vascular compartment where it produces magnetic field inhomogeneities in the surrounding tissues that result in decreased signal intensity. The contrast then passes into the extracellular space at a rate determined by microvessel permeability, surface area and blood flow. Thereafter, it diffuses freely within the interstitial space over a time period that depends on the structural integrity of the tissue in question. MRI sequences have been designed to be sensitive to specific phases of this movement of contrast. Work in cervical cancer has demonstrated that qualitative and quantitative parameters derived from contrast concentration uptake curves reflect tumour hypoxia[2], and that these low-enhancement areas are predictive of local recurrence[3]. However, more evidence of histopathological correlates is required before DCE-MRI is used routinely in radiotherapy planning.

BOLD-MRI capitalises on the differing magnetic properties of oxygenated and deoxygenated blood. Oxyhaemoglobin contains iron in the Fe^{3+} (diamagnetic) state whilst deoxyhaemoglobin contains iron in the Fe^{2+} (paramagnetic) state. Microscopic field gradients in the vicinity of red blood cells and vessels are modulated by changes in the paramagnetic deoxyhaemoglobin concentration which lead to signal attenuation in T2 sequences, such that areas of hypoxia are seen brightly on BOLD-MRI[4].

MRS is a non-invasive technique for measuring biochemicals such as choline, creatine, N-acetyl aspartate and lactate that are present in tissue at concentrations of a few mM. MRS of prostate cancer shows elevated choline and reduced citrate whereas benign prostatic hyperplasia is characterised by high citrate levels. Hence, the choline/citrate ratio can distinguish between malignancy and hyperplasia[5,6].

Targeting hypoxic biological sub-volumes identified by these functional imaging modalities with a higher dose than neighbouring tumour cells requires intentional creation of dose inhomogeneity, such that hot-spots coincide with the functionally-guided biological target volumes. This dose 'painting' is possible using inverse-planned IMRT[7] (See Figure 1).

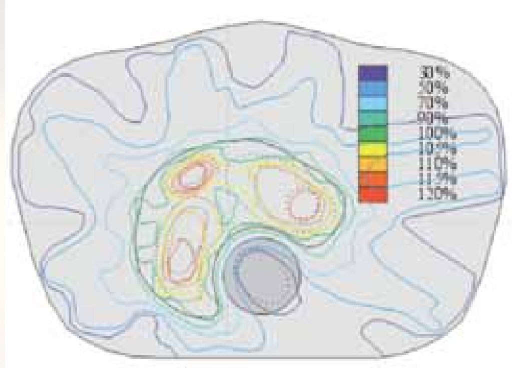


Figure 1: 'Dose-painting'. Dose distribution for treatment of a U-shaped target volume (black outline). Hotspots within target designed to coincide with areas of hypoxia identified on imaging.

At present, radiotherapy planning cannot be performed on MR data alone due to its lack of electron density information. Accurate co-registration of imaging modalities with CT is therefore crucial and, with the exception of the brain (which moves negligibly within the skull), is made difficult by variability in patient position and internal organ motion. Hybrid PET-CT scanners can acquire spatial and functional information within the same procedure, so minimising differences in patient position but not entirely overcoming problems with internal organ motion. Techniques

> 'Advances in imaging technology have been driven by the needs to increase sensitivity, specificity, and accuracy.'

using deformable image registration are able to superimpose CT data (for example, for prostate cancer, capsule and gland) on anatomical MRI but remain investigational[8] at present and are not yet in clinical use in the UK.

In addition to spatial and functional imaging, data can be acquired in a fourth dimension, that of time[9]. Multislice CT scanners can demonstrate the effects of breathing upon the position of either tumour or organs-at-risk throughout the respiratory cycle, cine magnetic resonance can provide data demonstrating temporal changes in tumour and normal tissue, and four dimensional PET (4D-PET) scanning is currently under investigation[10].

The role of imaging in verification of target volume and/or normal tissue position

Having defined target volume as accurately as possible, it is essential to ensure that the radiation dose is being delivered to the target as planned. Verification imaging can be acquired before, during or after a particular fraction, and is used to reposition the patient if significant misalignments are detected. The frequency of verification imaging in a course of radiotherapy is decided upon as part of the local quality assurance programme, and must balance the need to intervene to reduce errors as soon as possible with the extra time needed to acquire, check and act upon verification data.

The use of imaging in on-table verification is limited to that which is currently technically compatible with a linear accelerator. Since the 1990s, megavoltage electronic portal imaging devices using amorphous silicon flat panels have been used widely to obtain orthogonal megavoltage images of the treatment volume. Anatomical features, usually skeletal, are identified on each two-dimensional (2D) image and compared with digitally-reconstructed radiographs derived from planning CT data, such that set-up errors may be estimated in three dimensions (3D).

Where the position of a tumour cannot be related to skeletal anatomy, it can be localised instead by imaging radiographic markers implanted within, or adjacent to, the tumour; for example, gold seeds inserted into the prostate gland[11].

Megavoltage portal images are inherently low contrast and require administration of 4-16cGy per image pair, providing the impetus to develop more efficient detectors and machine- or room-mounted kilovoltage x-ray tubes.

Kilovoltage radiographs yield higher contrast images for a lower radiation dose (0.5-4cGy), allowing more frequent imaging of anatomy, tumour, or fiducial markers, throughout the treatment course and even within a treatment fraction.

Shirato et al have used room-mounted kilovoltage fluoroscopy to track radio-opaque markers within tumours in real-time, synchronising the linear accelerator to irradiate only when the markers are present within a pre-defined volume. This allows delivery of maximal dose to target and minimal dose to surrounding normal tissue[12]. An alternative strategy would be for the linear accelerator to track the movement of the tumour, and this is demonstrated by the Cyberknife™ (Accuray, USA), which consists of a compact 6MV linear accelerator attached to a moving robotic arm. The machine tracks surrogate markers within the target as it moves, correlating the treatment beam with these movements so that the target is never outside the beam[13].

Although the use of 3D multimodality imaging is now widespread for radiotherapy planning purposes, its use in verifying anatomical position at the time of treatment delivery is still in the early stages of development.

Trans-abdominal ultrasound was one of the first methods used for volumetric imaging at treatment delivery and has been used for pelvic and upper abdominal image guidance[14,15]. It is widely available and fairly inexpensive but disadvantages include generation of reflections by bone or air cavities which interfere with ultrasound signal from soft-tissue targets; distortion of the tumour's position by the ultrasound procedure itself, and highly variable inter-user technique[16].

The use of kilovoltage CT to obtain 3D information was initially achieved by placing a conventional CT scanner in the treatment room such that the gantry axis of the linear accelerator was co-axial with that of the CT scanner. Using this system, the imaging and treatment isocentres can be easily matched but are not coincident[17]. Current integrated linear accelerator-CT scanner systems (eg ExaCT™, Varian Medical Systems, USA) allow diagnostic quality CT, and have been used to monitor volumetric change during radiotherapy in head and neck cancer[18], as well as to alter treatment fields in lung and upper abdominal tumours[19].

CT functionality has now been integrated into the linear accelerator eliminating the need for a separate CT scanner. Helical megavoltage CT scans can be obtained with a unit capable of continuous rotation around the patient whilst the couch is moving into the gantry (Tomotherapy™, USA). Single-slice or volumetric megavoltage images of the irradiated region can be reconstructed[20]. The system combines megavoltage imaging with intensity-modulated radiotherapy delivered by a narrowly collimated fan beam. Advantages of this strategy are that images are obtained during radiation delivery allowing for daily adaptations to treatment volume if desired, and that it is possible to reconstruct the dose delivered on a daily basis[21]. Disadvantages are that higher doses are needed than for kilovoltage imaging and that methods to account for organ motion due to respiration are complex and not yet fully developed.

Cone-beam CT also integrates CT functionality with the linear accelerator. Most commercial systems are based on either an additional KV system, including a kilovoltage tube and flat-panel detector[22], (eg Synergy, Elekta Oncology, Sweden) or the use of megavoltage radiation from the therapy beam source (see Figure 2). Cone-beam CT obtains a series of planar images in one rotation of the gantry around the patient. Typically, hundreds of projections are acquired over a 30 second to two minute interval, and are reconstructed tomographically to verify soft-tissue position. The central axis of the kilovoltage beam is perpendicular or parallel to the treatment megavoltage beam, and the same centre of rotation is shared between these two beams. It is thought that on-board imaging devices with a separate KV system offer the greatest flexibility with regards to different modes such as fluoroscopy and CT, albeit that the latter is not of diagnostic quality. Furthermore, CT images take too long to acquire to be usable in real-time volumetric imaging. Kilovoltage cone-beam images have, nonetheless, been acquired in most body parts for verification and for image guidance[23,24]. Scans have also been sorted on the basis of respiration phase to produce 4D-kilovoltage cone-beam CT for liver and lung cancers[25].

Figure 2: A linear accelerator with on-board kilovoltage CT capability

The use of imaging in correction strategies for set-up error (verification continued)

Changes in position of external or internal anatomy can lead to reduced dose to the target and increased dose to normal tissues. For example, day-to-day variability in position of the prostate gland and lung/liver tumours (due to breathing) have been well-documented[26,27] qualitatively. Now, quantification of positional variability using imaging can guide the development of verification strategies. For example, analysis of verification images of the diaphragm in treatment of liver tumours indicates that the intra-fraction change in position of the diaphragm relative to the vertebral bodies is limited (SD 1.5-2.5mm) but that day-to-day variability is greater (3.4 - 4.4mm)[28]. This has provided a rationale for daily image guidance for upper abdominal cancers that are immobilised by breath-hold techniques. Furthermore, it has been demonstrated that day-to-day variations in tumour and organ position cannot be related linearly to skeletal anatomy such that current methods of verification using megavoltage imaging are unreliable. There are two main approaches to quantification and correction of set-up errors[29]. Offline strategies acquire a number of daily images (typically three or more) and use statistical analysis to calculate the systematic (mean offset) and random (standard deviation) components of the patient's set-up error. A correction for systematic error is then made for the remaining treatment fractions[30]. Online strategies acquire and assess information from daily imaging, typically before each treatment fraction is delivered, implementing simple corrections for detected deviations in patient position that exceed a predefined threshold. On the whole, online correction strategies achieve a greater overall reduction in error albeit at the expense of increased time, effort and imaging dose. As such, online strategies tend to be limited to tumours which lie in close proximity to important normal tissues and/or for hypo-fractionated treatment schedules in which large doses are to be delivered at each fraction such that a geographic miss would have serious consequences for both tumour control and normal tissue toxicity. Adaptive radiotherapy refers to the practice of re-planning an individual's radiotherapy in the light of patient-specific information acquired using image guidance. Using the offline approach, calculation of a patient's random set-up error after the first few fractions allows development of a new plan based upon the average position of target volume and organs-at-risk. With the online approach, re-planning could take place prior to each fraction, based upon the volumetric image acquired that day. The latter is, clearly, not currently feasible in routine clinical practice but it may become so with improvements in automation of tumour and normal tissue contouring, planning, deformable image registration, and error correction. In the meantime, some centres undertake daily images but re-plan only when changes in tumour or healthy tissues are beyond a predefined, clinically meaningful threshold.

Benefits of image guided radiotherapy (IGRT)

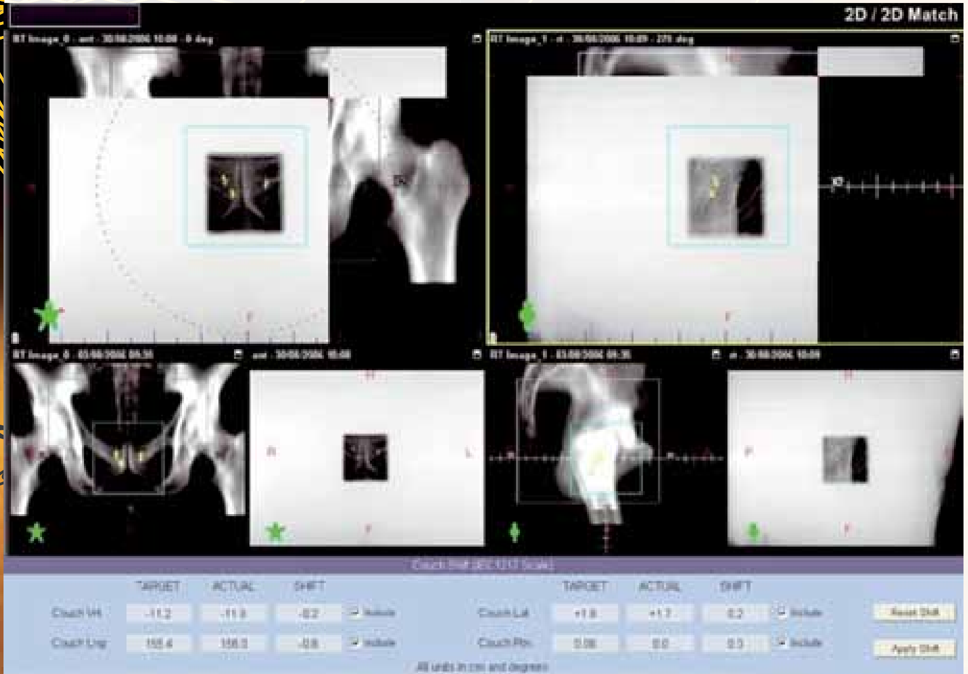
Increased geometric precision

As quantification of and adjustment for variability in patient position and organ motion using megavoltage and kilovoltage imaging takes place, with or without fiducial markers, the margin of tissue that must be added around the clinical target volume (CTV) to form the planning target volume (PTV) can be decreased. For example, real-time tumour tracking has reduced the range of motion of lung GTVs within a radiotherapy field during radiotherapy from 9.6 - 38.4mm down to 2.5 - 5.3mm, lessening the volume of healthy tissue irradiated[12].

'Fully online adaptive planning, incorporating sub-millimetre geometric precision, is tempting.'

In patients with prostate cancer, KV cone-beam CT guidance with automated registration of three fiducial markers in the prostate has been compared with image guidance using the whole prostate[23]. The average difference in residual error between fiducial marker and prostate guidance was 1.1mm (SD 2.9), suggesting little difference with either cone-beam strategy for prostate cancer. Another study showed the feasibility of automated prostate-to-prostate registration, making soft-tissue image guidance more practical than previously for routine clinical use[31]. Observer variability of various image-guidance correction strategies has been assessed in a study of megavoltage CT for prostate-cancer guidance which found that fiducial markers were associated with the smallest inter-user variability, followed by anatomy-based and contour-based registration[32] (see Figure 3).

Figure 3: The use of intra-prostatic fiducial markers in the quantification of set-up error.



Improvements in dose distribution

Another method of assessing the benefits of image guidance strategies is to measure dose variations in target and normal tissues. Ghilezan and colleagues investigated the potential benefits of online volumetric image guidance and re-planning in 22 men with prostate cancer[33]. The standard plan, without image guidance, used a 1cm CTV to PTV margin. Image guided plans were created by adding together dose delivered on the basis of plans generated from multiple (median 18) CT-planning scans obtained throughout the radiotherapy course. The equivalent uniform dose to the target rose from 96.8% (SD 5.6%) to 98.9% (SD 0.7%) with guidance, and there was reduced variability in the dose delivered ($p<0.0001$). Furthermore, the target dose could be augmented by an average of 13% with online guidance, for the same rectum dose limit. Assuming an estimated 3% rise in tumour-control probability with every one Gray increase in dose, a 13% boost in dose (to 79Gy) should enhance the probability of tumour control by 33% and of 5-year survival by 10%. In lung cancer, adaptive re-planning based on serial megavoltage CT-imaging during radiotherapy has resulted in an average reduction of 21% in the volume of lung receiving 20Gy or more[34]. In head and neck cancer patients, repeat volumetric images acquired over the course of treatment show systematic alterations in shape and position of tumour and normal tissue leading to potential tumour underdose and spinal cord overdose[35]. The dosimetric benefits of adjusting treatment plans for such changes in anatomy are increasingly being quantified[36].

Consistency of dose delivery for the purposes of multi-institutional trials

The ability, using IGRT, to deliver prescribed dose as planned through enhanced geometrical and dosimetric precision, should increase uniformity of dose delivery within multi-institutional clinical trials. Consistency of dose delivery should augment the ability to measure the effect of dosimetric and non-dosimetric factors on tumour control and normal tissue complication risk.

Improved local control and survival

Whether or not geometrical and dosimetric benefits of IGRT translate into clinical benefits is difficult to prove. Randomised trials treating patients with and without image-guidance strategies are unlikely to be undertaken although, where imaging strategies facilitate use of radiotherapy for new sites or applications, randomised trials should be pursued. Prospective studies to assess treatment techniques and patterns of recurrence provide some evidence for the clinical benefits of IGRT. For example, multivariate analysis of patients with medulloblastoma treated with radiotherapy indicated that the correct placement of radiation fields was significantly correlated with supratentorial recurrence-free survival[37]. In prostate cancer patients, a full rectum at the time of radiotherapy planning has been associated with a worse 5-year prostate-specific antigen (PSA)-free survival compared with an empty rectum (92% vs 63%, p=0.003)[38]. The assumption is that significant initial rectal distension reduces throughout a course of radiotherapy (see Figure 4 overleaf), such that the prostate gland shifts posteriorly with consequent underdosing

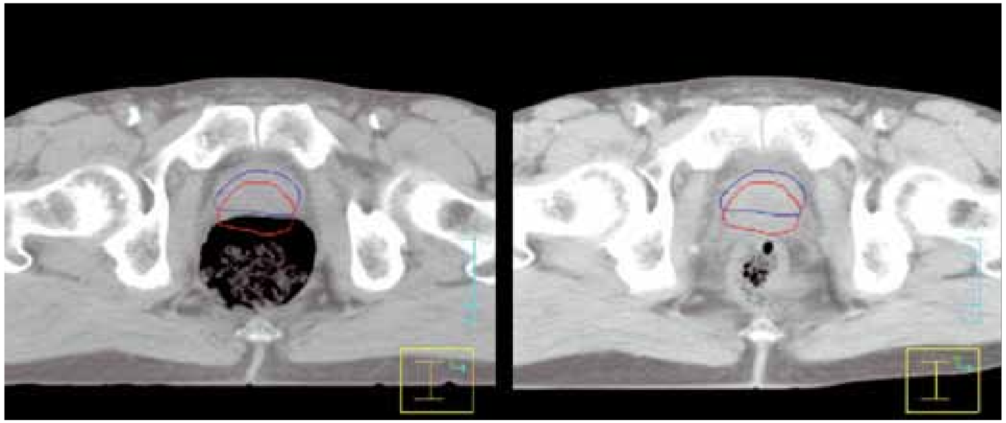


Figure 4: The effect of changes in rectal filling upon prostate position

of the posterior part of the prostate and increased risk of relapse. IGRT would, clearly, be helpful in this situation.

Limitations of IGRT

Technological advances in image guided radiotherapy have great potential to improve clinical outcomes, but there is a need to remain pragmatic as these advances are steadily integrated into the routine practice of radiotherapy departments in the UK. The pursuit of fully online adaptive planning, incorporating sub-millimetre geometric precision, is tempting, but must be balanced against the likelihood of only modest clinical gains, and the certainty of increasing workload in radiotherapy planning, delivery and verification processes. As treatment becomes ever more geometrically precise, the accuracy of target delineation must be improved simultaneously, making full use of advances in functional imaging described above.

In the development of an image guidance strategy, the clinical needs and workflow of a department must be considered together with the practicality of use of image guidance technologies appropriate to those needs. Costs include initial financial investment, employment and training of an increasingly skilled workforce, data storage, equipment maintenance, and the potential for reduced throughput of patients because of increased time required for image acquisition and decision making. Skills mix within the department will need to be considered and, where appropriate, responsibilities for image assessment and decision-making delegated to treatment radiographers. Improved decision-support strategies and correction algorithms are also necessary to avoid time delays and errors at the time of treatment.

It is necessary to remain aware of the potential for false reassurance from IGRT leading to inappropriate margin reduction. Formal quality assurance procedures and education programmes will help in avoiding such problems as IGRT is rapidly disseminated into clinical practice.

Finally, concerns have been raised regarding extra radiation doses administered to patients for the purposes of IGRT. These are extremely low compared with treatment doses and are likely to be clinically unimportant for the majority of patients. Nonetheless, long-term follow-up of patients treated in the modern era of image guided and intensity modulated radiotherapy is required before the actual risk of side-effects (including second malignancies) from low-dose irradiation can be determined[39].

Conclusions

Advances in imaging and image-registration techniques have led to enhanced 4-D definition of target volumes for radiotherapy planning purposes. Uncertainties regarding organ motion and patient set-up are now quantifiable and can be corrected for, such that radiation dose is much more likely to be delivered as intended. Precision and consistency in radiation dose delivery will, in turn, facilitate more accurate appraisal of the effect of dosimetric and non-dosimetric factors on both tumour control and normal-tissue complications.

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Radiography: The future is global

Warren Town

Introduction

Much of our existence today is governed by factors outside of our control. Our food, our clothing, and our wealth and possessions are sourced from the global market place. How we live and how we survive is, increasingly, dependent on how others, far distant from us, make use of their skills to produce the goods and services we consume. This global economy and market is the basis on which it is argued that the world is shrinking. No country today, no matter how powerful, can ignore the influence that this global economy and market will have on the health and wealth of its people.

As more of the world's population becomes dependent on the global market place and so on each other, other factors come into play. These include:

- Global warming, driven by the increasing need to access sources of power to process raw materials;
- Changing demography, especially in the developing economies;
- Increased migration and access to world travel;
- New technology; and
- World conflict.

These factors create dynamics in healthcare services and delivery that mean even the most advanced, or affluent, economies struggle to pay for, or to develop.

> 'The state will no longer have the power to direct the delivery and direction of healthcare.'

Western public health

In the United Kingdom (UK) and throughout the western world, the concept of a public healthcare system, funded by taxation and accessed by all, is under threat. None have yet completely abandoned the use of taxation to fund healthcare. Instead, most have opted for, or are in the process of moving toward, a mixed economy where central funding is complemented by the injection of private monies, and capacity is increased by extending access to services in the independent healthcare sector. This co-existing use of public and private services is referred to commonly as the 'pluralistic model' for healthcare.

In economies where the traditional model of healthcare delivery has been supported by the public purse and managed by the government of the day, the shift to the pluralistic model has been controversial, and treated with suspicion by the electorate, the trade unions and the professions. Traditionalists predict that this model will do no more than accelerate the loss of free healthcare, cause a decline in services and support for those who need these most, and produce an unhealthy reliance on multi-national and insurance companies. Ultimately, the state will no longer have the power to direct the delivery and direction of healthcare services for its population.

The contrasting view of modernists, who promote plurality and reduced reliance on the state, is that private money and services will drive innovation, increase competition and, hence, improve the management and delivery of healthcare. Whether a traditionalist or a modernist, the fact remains that, good healthcare is expensive for any government. As a result, maintaining the status quo is not an option and, in the UK, this is resulting in a shift away from a system which has relied for many years on the large, acute hospital as the focus for the delivery of services. Additionally, politicians no longer refer to 'healthcare for all', preferring to use terms such as 'mixed health economies', 'choice', and 'quality' instead, and linking these to 'value for money' and 'efficiency'.

Healthcare a commodity?

Healthcare is no longer a simple message about caring for the sick. It is now a commodity; a system in which every diagnostic test or treatment has a price and every person who uses the system is a cost. In the UK, there is now a litany of catch phrases used constantly by politicians. Key amongst these are 'money follows the patient'; 'payment by results' and 'tariffs'. All, of course, relate to the cost of healthcare and not to the quality of either the healthcare provided, or the service delivered.

> **'Healthcare is now a commodity; a system in which test or treatment has a price and a person who uses the system is a cost.'**

As this ethos prevails and is promoted, so will the public begin to believe that the pluralistic model for their national health service will be the only show in town. This acceptance that healthcare is a commodity will, in turn, pave the way for accepting that direct payment for diagnostics and treatments will become the norm –

'After all, isn't my health my responsibility as much as it is the state's and shouldn't I be prepared to contribute to my own well being?'

– may well be the understanding of the next generation.

What of general practice?

With the caveat that the socially disadvantaged and those who cannot help themselves will be protected, the future for healthcare may be even more of a mixed economy than we think. The pluralistic model will encompass more than just private healthcare service providers and the state; a third significant investor will join the healthcare market and visits to a general practitioner (GP) will become much like visits to a dentist at present.
Payments up front will be made by clients (not patients) to their GP or their healthcare clinic, so providing access to a minimum level of healthcare.
This is likely to include a threshold for investigations to establish the root cause of any illness. Anything above and beyond the threshold will have to be funded by the individual or through healthcare insurance. Such a model will have profound effects on the structure and delivery of diagnostics and cancer services, employment patterns and the profession of radiography (as well as most other healthcare professions).

Radiography in the global healthcare market

Diagnostics

The shift away from healthcare provision to services delivered to patients will support the development of the independent, autonomous practitioner undertaking the full role of a diagnostician. A core of staff providing comprehensive diagnostic services in the hospital setting will remain but there will be a most dramatic shift away from these towards the delivery of diagnostics in what will be a plethora of independent clinics and combined services providers who, in turn, will contract out these services in the community.
In terms of employment, the traditional, single contract with one employer model will decline and radiographers will offer their services and skills to the many providers of diagnostics under a 'contract for services' arrangement, and these may be for a set number of

'The state manages the delivery of cancer care but is not the provider.'

hours, for a fixed term, or according to some other ‘pricing’ arrangement. Radiographers engaging in these contracts for services will need to carry with them their own professional liability arrangements, and be responsible for their own professional development. But, they will be able to sell their services in the global marketplace and negotiate the prices they charge for those services.

Cancer care

Cancer care is not immune to the changes taking place globally and will also see the development of a mixed economy whereby the state manages the delivery of cancer care but is not the provider. Services, including radiotherapy, will be delivered in the community. The challenge for therapeutic radiographers is to diversify and develop a range of skills to ensure that, like their diagnostic counterparts, they are able to provide, and so bid for, services in the global marketplace. Importantly, they will not be able to simply assume that employment will be available.

In summary

It would be naive to think that the current changes to the funding and delivery of healthcare in the UK are unconnected with what is happening elsewhere in the world. They are, without doubt, related inextricably. The market for radiography services will, increasingly, come from across the globe. Technological advances in global communications will allow remote access to services. Indeed, this is the case already, with the main stumbling block at present being a lack of co-ordination rather than a lack of capability.

Increasingly, there will be more open recruitment for radiographers’ skills across Europe and globally. Highly skilled UK radiographers, both diagnostic and therapeutic, will be in demand but only if they understand how the market is changing and respond accordingly. If they fail to do this, others will step in and the profession will become fragmented at first, and, in the longer term, lost altogether. It is vital, therefore, that the profession and its leaders prepare and respond now.

Warren Town is director of industrial relations at the Society and College of Radiographers.

> **The profession will become fragmented at first, and, in the longer term, lost altogether.**

Leadership in the development of the radiographic profession

Peter Hogg, Dianne Hogg and H Brian Bentley

Introduction

Throughout the history of the radiographic profession, leaders have played important roles in its formation and evolution. These leaders may not have realised they were displaying leadership characteristics and, indeed, their co-workers at the time may not have realised this either. This article analyses the development of the radiographic profession to assess the role that leadership has played in its formation and evolution. In doing so, it uses the Kouzes and Posner[1] model of leadership, and concentrates on the profession as it has developed in the United Kingdom (UK).

A model of leadership

There is considerable variety in views about what is leadership but, for the purposes of this debate, Kouzes and Posner's transformational leadership model has been used. The model takes a non-threatening approach that encourages, rather than enforces, the adoption of new ideas and ways of working, and suggests that there are five core behaviours that influential people demonstrate when at 'their personal best'. These behaviours comprise:

- Challenging the process;
- Inspiring a shared vision;
- Enabling others to act;
- Modelling the way; and
- Encouraging the heart.

'There is a move away from being an expert to being engaged in effective CPD.'

'Challenging the process' involves looking for opportunities to change the status quo, implementing innovative solutions, experimenting and taking risks, and recognising failures as opportunities from which learning can arise. 'Inspiring a shared vision' is about leaders articulating their dreams of what the future will be like and enlisting others into those dreams through personal magnetism, quiet persuasion, and exciting people around them. 'Enabling others to act' involves collaboration and the building of teams by the active involvement of others. Such collaborative working involves mutual trust and the development of others in a way that makes them capable and powerful. 'Modelling the way' is associated with being a role model, removing bureaucracy when it limits action, and putting up signposts to help people see the way forward, so creating opportunities for victory. 'Encouraging the heart' is about recognising and valuing the achievements of people, and making them feel like heroes.
Leaders need to demonstrate more than one or two of Kouzes and Posner's leadership behaviours when leading, and the behaviours identified should not be seen in isolation because they impact upon each other. However, it is possible for a leader to be stronger in some of the identified behavioural traits than others.

A definition of a profession

Downie[2] defined some important characteristics of a profession. These included:

- The requirement for a well defined skill-base proceeding from a profession-generated knowledge base;
- Being educated rather than simply being trained;
- Being independent of external influence;
- Being bound by a code; and
- Having autonomy and freedom to act.

In some respects, current events, particularly within healthcare, have started to evolve this traditional definition of a profession; for example, there is a move away from being an expert (the well defined skill base) to being engaged in effective continual professional development. Additionally, self regulation and autonomy is being modified to accountability, openness and external regulation.

Radiography: 1895-1980

Within a short time of their discovery, x-rays were being used for medical purposes and, soon after their application to medicine, there was a requirement for 'equipment operators' to be employed to produce the medical images required by doctors. These 'equipment operators' evolved subsequently into radiographers.
In 1910, the first radiographer hospital training programme commenced[3] and in 1917 the first formal teaching programme began[4]. In 1920, the [UK] Society of Radiographers was founded and in 1935 the journal *Radiography* was established as the journal for British radiographers and their practice. Other early radiographic literature began to emerge; for example, Positioning in Radiography by KC Clark[5]. The development of the radiographic knowledge base followed slowly behind the clinical evolution and, surprisingly, the rate of knowledge development did not appear to keep pace with advances in clinical roles. The year 1925 saw the culmination of the long-running dispute between radiographers and radiologists over the division of labour. The outcome prevented non-medical members of the Society of Radiographers from reporting, a decision which forced the Society of Radiographers to change its Articles of Association accordingly and, so determined the occupational boundaries of radiography[6] and the direction of radiographic practice for decades to come. This division was reaffirmed from time to time over the years, with comments appearing in the literature to remind the profession of its core business of image acquisition. A typical example was the comment by Furby[7] who wrote:
"Some consider the inclusion of pathology in the [radiography] curriculum as having an element of danger in that there would be a tendency for the operator to attempt interpretation"
By the 1970s comments began to appear that attempted to challenge and extend the traditional core role of radiographers, with Swinburne's article[8] on pattern recognition for radiographers the most well-known. Regardless of such emerging challenges, what was quite clear was that by the 1970s radiographers had well defined roles in medical image acquisition, using a range of scientific principles and technologies. Reflecting this, a range of post-basic/post-qualifying education courses started to appear from the early 1970s and, by the mid to late 1980s, a growing number of radiographers were becoming more assertive in challenging the boundaries of their clinical roles. As a consequence, major advances in professional development started to ensue.

Analysis 1895-1980: Professionalism

Applying Downie's characteristics of a profession, it is clear that radiography had met some of the criteria by the end of this time period. It had a clearly defined skill base, although examination of the literature indicates that this was provided predominantly by other professional groups. Radiographers were being trained and associated underpinning theory was being addressed within the training programmes. However, the mechanisms of learning as inferred from the syllabi produced by the Society and later the College of Radiographers revolved around rote learning and recall of factual knowledge. As such, critical thinking and research skills were not evident, which is a deficiency in Downie's terms. Radiographers did have a code of practice that defined what they could and could not do, and regulation was evident by the end of the period with the establishment of the Council for Professions Supplementary to Medicine in 1960. Continual professional development began to be discussed in the latter part of the early years but autonomy and freedom to act were severely limited as can be seen in the codes of conduct and the professional literature during this period.

Overall, by 1980, it was evident that radiography did not meet all of Downie's characteristics of a profession. However, by comparison with the early 1920s it was clear that great advances had been made, with some characteristics being met completely.

Analysis 1895-1980: Leadership

Leadership of the profession during this period can be examined by applying the five leadership behaviours identified by Kouzes and Posner.

Challenging the process:

The discovery of X rays and their use in medicine was, arguably, the first and greatest example of 'challenging the process' in radiography. Since then, frequent opportunities have arisen where leaders have moved radiography forward, including the introduction of radiographers in the early days of the 20th century and the focusing of the profession to the core responsibilities of image acquisition in 1925, through to the introduction of the concept of CPD in the 1970s. The events of 1925 have previously been viewed as inhibiting rather than innovative but it could be argued that these enabled the continued formation of the well defined core image acquisition role that radiographers have today.

Inspiring a shared vision:

The foundation of the Society of Radiographers and its subsequent work led the way in envisioning the future of radiography, inspiring others to believe in and take forward this future. The journal *Radiography* formed the medium through which leaders could inspire others in large numbers and its peer reviewed status increased its credibility. KC Clark's book 'Positioning in Radiography' was, and still is, a vision of excellence in radiographic positioning. Its accessibility meant that all radiographers had the potential to excel and so optimise their contributions to patient care.

Enabling others to act:

The foundation of training and, later, education programmes enabled standards to be set, attained and exceeded. These programmes formed the cornerstone for the development of the profession and enabled individuals to identify with and own their skills as radiographers.

Modelling the way:

KC Clark published one of the first books by a radiographer. In this, she set the example of excellence in radiographic positioning, with clear aims and expectations. The publication was so successful that Clark updated and republished it on several occasions and, since her death, the book continues to be updated and republished by other authors regularly.

Encouraging the heart:

The Society of Radiographers, through *Radiography*, recognised the contributions that leaders were making and celebrated them visibly by publishing their research findings and opinions within this journal.

> 'A decision which determined the occupational boundaries of radiography.'

'Medical imaging is on the cusp of fundamental change.'

Radiography: 1980-2007

The past thirty years has witnessed major advances in medicine, including in medical imaging. During the period, medical imaging became capable of resolving minute detail, through modalities such as high resolution computed tomography (CT) and magnetic resonance imaging (MRI). Highly sensitive methods are now available for imaging physiology, through both ‘traditional’ nuclear medicine methodologies and through the rapidly emerging field of positron emission tomography (PET). Modalities like ultrasound and MR have particular values because of their lack of radiation. Notwithstanding such advancements, the use of X-rays continues to have an important place in imaging.

The creative use of medically-orientated technologies, particularly applied to physiological imaging, has enabled the mysteries of complex organs such as the brain to be unlocked. Exquisite functional and anatomical maps of these organs at rest, under stimulus, and insulted by a range of different pathologies are now available. Not content with these advances alone, there has been a rapid move towards hybrid imaging which allows functional and anatomical images to be co-registered at the point of image formation. Common examples of hybrid imaging include PET-CT and SPECT-CT (single photon emission computed tomography and CT), and it is expected that PET-MR will become a routine clinical reality soon.

Again, medical imaging is on the cusp of fundamental change and the next 50 years is likely to be the age of genomics. As a consequence, molecular imaging will enable the detection and treatment of disease before patients become symptomatic, driving change in the delivery of healthcare and minimising the need for surgery and biopsies considerably. In this respect, PET-CT and PET-MR will grow in importance, as will optical imaging.

Clinical roles of radiographers have evolved rapidly during this period, too, and particularly since 1990. The work of Price[9] and others provides documentary evidence to support this claim. Certain ‘first post’ radiographer roles have been derived from radiologist roles and have become embedded in pre-registration, qualifying education programmes at first degree level. Advanced clinical roles, again derived from the medical profession, have been developed within a postgraduate education framework. Accompanying this shift to under- and post-graduate education has been a growth in radiographer research skills and awareness with consequent growth in radiographer-performed research.

As radiographer education moved into the higher education sector in the UK, research and critical analysis skills became mandatory, and part of the skills required of radiographers.

It is important to understand what has brought about the changes to radiographer roles, particularly given that advancement of the profession beyond the image acquisition process was inhibited previously. Policy documents from various sources and new legislation were important catalysts for role advancement. Classic examples include: the National Health Service and Community Care Act 1990[10], under which Hospital Trusts could be created. These employers then became the decision makers in regard to those they employed and what the professional roles of their employees encompassed. In 1998[11], the Society of Radiographers, together with the Royal College of Radiologists, issued a joint statement that indicated a clear direction for radiology/radiography services to further enhance the career aspirations of radiographers. This identified that by engaging in role advancement for radiographers, patients could be offered better services. In 2000 the Department of Health[12] released 'A Health Service for all the Talents – Developing the National Health Service Workforce', giving further emphasis to new ways of working that utilise advanced roles. In fact, the Department of Health and professional bodies in radiology/radiography issued many policy and guidance documents to encourage the growth of advanced roles for radiographers, as well as other non-medical professional groups.

The response to these national initiatives was massive interest and growth in new roles, alongside which came more rigorous and demanding codes of conduct for radiographers and the much increased possibility of clinical negligence claims. The accountability of radiographers increased enormously, therefore.

Whilst top-down initiatives had their place in the development of advanced roles their widespread adoption would not have occurred if radiographers had not demonstrated that the new roles were effective. Dissemination of information through conferences and journals was very important in assisting the evolution of clinical roles. An example, in 1994, was the article by Loughran[13] illustrating that radiographers can report x-ray images to a good standard. Figure 1 illustrates the timing of Loughran's publication in relation to the uptake of this role nationally. This was first noted in 2003[14].

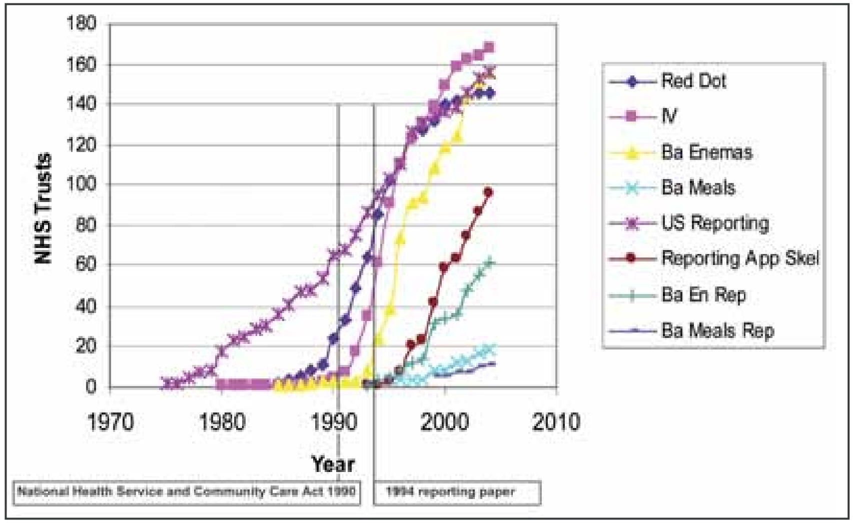

Figure 1 Adoption and diffusion of advanced roles

On examining Figure 1, it becomes clear that Loughran and co-workers were implementing the radiographer reporting role well before most others. Additionally, the paper was published very early in the take up of this new role for radiographers. Shortly after publication, there was rapid growth of university-based courses addressing this specific practice (radiographic reporting) and consequent rapid growth of the role. It is not clear how much importance publications of this type have in the advancement of clinical roles but it is reasonable to assume that they do have some effect. Anecdotal evidence also supports this view.

A similar argument could be applied to legislation. Again this is demonstrated in Figure 1 which shows rapid growth of advanced roles after the implementation of the National Health Service and Community Care Act[10] in 1990.

> 'It is essential that policy makers recognise that the changes they desire are brought into being by local trail-blazers.'

Accompanying advanced roles and pre-requisite requirements to hold first and higher degrees, the knowledge base of radiography began to develop at a significantly faster rate than previously. Importantly, this knowledge base development has been increasingly under the leadership of radiographers and, in the period from 1980 onwards, a considerable number of books and journal articles have been published with radiographers as first and co-authors. The journal *Radiography* established itself as a well respected, international peer reviewed journal and other journals specifically for radiographers also appeared and established themselves. Additionally, radiographers published in other journals, including those primarily with medical and nursing readerships.

Analysis 1980–2007: Professionalism and leadership

Reviewing Downie's characteristics of a profession[2] as applied to radiography, it is clear that the knowledge base of the profession has increased significantly, partly from research findings contributed from outside the profession and partly by radiographer-generated research. Evidently, too, the radiographer-generated evidence base is growing in its extent and in its relationship to practice. Indeed, the requirement to base evidence upon practice has become increasingly important and this is associated closely with professional accountability. In the late 1980s/early 1990s, there was a major shift from a predominantly hospital-based training system to university-based education and training programmes. Since 1980, too, there have been several revisions to the profession's code of practice and the most recent[15] is far reaching in terms of practice and competence to practice. As the most recent code demonstrates, autonomy and freedom to act have increased considerably, especially for advanced and consultant practitioners. Radiographers continue to have professional regulation and, overall, it is evident that radiography has moved a considerable distance along the path of becoming recognised fully as a profession.

It is also interesting to apply Kouzes and Posner's five leadership behaviours to the development of radiographic profession during this most recent period.

Enabling others to act:
Obtaining the Diploma of the College of Radiographers (formerly Membership of the Society of Radiographers/Diploma of the Society of Radiographers) enabled individuals to study for the Higher Diploma of the College of Radiographers. However, few radiographers did so and a significant shift in focus became necessary to support the further academic progression of the profession. This came towards the end of the 1980s when the College of Radiographers determined to move away from offering its own diploma level qualification and championed first degree level education as the route to qualifying and registering as a radiographer. This enabled radiographers to enter higher education and progress to higher degree level education, and to bring into radiography the additional values associated with being a graduate profession.

The massive developments in technology during the period, together with associated funding, also created a climate which, at least for the politically aware, was highly enabling. Hence, healthcare policy in recent times, too, could be said to be an enabler for the development and expansion of radiography and the roles of radiographers. More likely, however, is that those who interpret policy into practice are the real enablers.

Challenging the process:
Government policy is often conceptual, necessitating adaptation and interpretation according to variables such as local need and existing local structure. The interpreters of policy challenge views and opinions, and even fundamental beliefs at times. Traditional roles, imaging modalities, and places where imaging takes place have all been challenged in recent times to better meet patient need. Challenge of the magnitude seen in medical imaging since 1980 is not without risk and, while a 'no blame culture' is gradually being engendered into organisations and professions, mistakes due to misjudged risk-taking can still, unfortunately, lead to punishment rather than learning. Unfortunately, too, this results in some perpetuation of the traditionalism and hierarchy that held back the profession in earlier times.

Inspiring a shared vision:
The current holistic view of the National Health Service (NHS) as described in government policy is, undoubtedly, influencing the vision of the radiography profession; discipline could not have progressed as it has if the NHS had not evolved.

Taking education from the diploma to first degree level showed mature vision and courage; it was, probably, one of the biggest steps in the profession's move from 'training' to 'education'. The document published by the College of Radiographers and the Royal College of Radiologists 1998[11] was itself visionary but, importantly, it built on the political climate of patient focus, and patient-focussed care. If the document had considered only the development of the professions, it may not have been as well received and implemented.

Encouraging the heart:
In the period 1980–2007, much more emphasis has been placed on those who achieve, not least by celebrating their successes. Annually now, the best clinical radiographers as identified by their peers and recognised by their profession are celebrated at the Houses of Parliament; the journal *Radiography* acknowledges its best research paper, and peer-reviewed conferences award

prizes. Additionally, individuals are encouraged by publishing their work in journals and books, and by being invited to speak about their work nationally and internationally.

Modelling the way:

The Society of Radiographers sets out standards that it expects radiographers to follow, and acts to remove or clarify bureaucratic and other barriers to practice development and the continuing development of the profession. Loughran and his radiographer colleagues were innovators; they forged the way ahead, then described the path for others, much as a guide might do through uncharted territory.

Effective professional development and leadership – looking ahead

There is no doubt that leadership has played a highly significant part in the development of the radiography profession. This is much in evidence at the national level and this article has featured some of the mile-stones in the profession's development. However, this development of the profession could not have occurred without there being clear professional leadership at the more local level. Leaders at the local level are more difficult to identify through the historical record and the current literature, but they are essential to improving service delivery at the NHS/patient interface where they share their vision of excellent care, and lead and implement change through others. The role of such radiographers cannot be over-stated and it is essential that this professional leadership at local level (as well as leadership at regional and national levels) must be sustained to enable the continuing development of both services provided and the roles of radiographers within those services.

It is acknowledged that investment in leadership development is somewhat random. It is also the case that radiographers, like other professions, need support and education to develop the skills of leadership or, to recognise such skills in themselves and others. A number of nationally and internationally recognised programmes exist to address leadership development needs, and the profession has set out its own core expectations of its leaders[16] but these alone are insufficient to secure professional leadership and, through this, secure continuing development of the profession and its contribution to healthcare. Rather, it is essential that governments and healthcare policy makers recognise that the changes they desire (or decree) in relation to the delivery of healthcare are brought into being by local leaders and trail-blazers in the healthcare professions, including radiography. The energy and skills of professional leaders should be harnessed to deliver the healthcare service required for the 21st century; advancement of the professions and clear investment in and support for professional leaders is in the clear interests of the NHS and the patients it is meant to care for.

Conclusion

Leadership and the development of the profession of radiography have gone hand in hand over the past hundred years, or so. Indeed, leadership has been crucial to the profession's development, and particularly so in the later decades. In terms of what is to come, excellence in professional leadership will be critical to support the need to develop the profession yet further, and make it fit to enter the molecular imaging and gene therapy era. Current and emerging leaders at local level will be essential – they need to invest significantly in their own development; leaders at regional and national level are vital – they must continue to enable, challenge, inspire and encourage, as well as to model the way.

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A compromised view of skill mix?

Richard Price

Richard Price presents one view of contemporary skill mix and Bev Snaith presents another. Both give their thoughts about the joint Royal College of Radiologists' and Society and College of Radiographers' publication, Team Working within Clinical Imaging – a Contemporary View of Skill Mix.

What is not in doubt is the increased capacity and capability of diagnostic imaging over the past two decades. The developments in technology in both hardware and software have made these possible. Hardware developments such as computed tomography (CT) and magnetic resonance imaging (MRI) have been made possible because of advances in computer technology, whilst the software advances have been in education, skills development and the adaptation of the imaging workforce.

Such developments have been recognised in a recent joint publication[1] by the Royal College of Radiologists and the Society and College of Radiographers entitled 'Team Working within Clinical Imaging – a Contemporary View of Skill Mix'. As the subtitle suggests, the document sets out only one view; there are, of course, others and one such view was expressed by Edwards[2] which was, on the whole, unfavourable to the publication. It was noticeable that in a response, Ian Henderson[3], co-chair of the colleges' skill mix steering group, indicated that reaching agreement on the document was not plain sailing. Nevertheless, the document states the agreed position between the two bodies.

There are valid points and good advice given in Team Working that cannot be disputed, and no one should deny the crucial responsibilities of consultant clinical radiologists, but it must be a concern that there is reference only to non-medical practitioners participating in clinical audit. There is factual information cited from the Health Professions Council (HPC) and General Medical Council (GMC) and, as far as team working and individual responsibilities are concerned, nothing new has appeared. Radiographers by virtue of regulation by the HPC and prior to that by the Radiographers Board at the Council for Professions Supplementary to Medicine will have long recognised their position and I am sure the same applies to radiologists within the GMC framework. What, therefore, was the point of the publication?

For one, the joint document clearly consolidates the position of the radiologists who are referred to throughout as consultant clinical radiologists, whilst radiographers are referred to as radiographers. Nothing wrong with the former and for probably good reason the Royal College prefers this terminology. On the other hand, surely a missed opportunity by the Society of Radiographers not to flag the significant developments made by radiographers in advancing their practice over the past decade and, crucially, the introduction of radiographer consultants.

The latter point was made by Edwards in her letter but this was discounted by Henderson who said consultant radiographers were not mentioned because the object of the document was to comment on organisation and governance of skill mix. Surely, the opposite must be true and the very reason why radiographer consultants should have been mentioned; the introduction of the 4-tier structure was about skill mix if nothing else. For the publication to make comment on assistant practitioners in radiography and not on consultant radiographers, is bizarre to say the least.

So does this mean that the Society and College of Radiographers do not have a formal position on radiographer consultants? The inference that can be drawn is that it is only consultant clinical radiologists who are important in matters of the organisation and governance of skill mix.

The position and status of radiographer consultants needs urgent clarification from the Society and College, even from the fundamental premise, is there a role for such an individual? I was invited to write an article[4] in the first publication of Imaging & Oncology which was entitled 'Critical Factors Influencing the Changing Scope of Practice; the defining periods.' The position of consultant practice in radiography was a concern raised in the article and questions were posed which have still not been answered.

Consultant radiographers are accountable for their practice and are answerable to the public via the HPC. So, by definition, they are autonomous practitioners and obviously responsible for their actions. Perhaps the root of the matter is that they are seen to be a threat to the existing status quo by being seen as independent practitioners; a status that some may find uncomfortable and a bridge much too far for a joint document. But what matters here is that individuals in consultant radiographer positions have the knowledge, skills, expertise and qualifications which are employed in the best interests of patients.

The Agenda for Change national profile for radiography consultants (diagnostic) states that they must have 'skills for interpreting, reporting on patient conditions, diagnosis from a range of options, possibly conflicting interpretation, recommending further action, changing practice'. These are certainly not descriptors for delegated roles but it would seem that the joint publication only recognises radiographers undertaking tasks that have been delegated. Is this the reality of practice in 2007?

Radiographers must be unique and very unfortunate in this respect because other allied health professional groups do not suffer from a similar hang-up that, for radiographers, has rumbled on since before the establishment of the Society of Radiographers in 1920. To ignore entirely the development and the role of senior positions in radiography in a document on skill-mix is a travesty and one which the Council of the Society of Radiographers needs to remedy. Given the apparent difficulties in agreeing the joint publication perhaps, more correctly, the subtitle should read 'a compromised view of skill mix'.

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Skills mix is here to stay

Bev Snaith

Guidance documents published jointly by professional groups are challenging for both authors and readers because they seek to develop shared understandings of particular issues and, through mutual respect, seek to deliver a vision for the future.

This is no less applicable than in the case of the recently updated skills mix guidance published by the Royal College of Radiologists and the Society and College of Radiographers[1]. I recognise, too, the frustrations of Richard Price and other radiographers who believe that the document appears not to go as far as radiographers would like in both recognising and promoting skills mix developments. Indeed, as Richard has clearly indicated, there have been many significant developments in the intervening years since the first joint document in 1998 and radiographers, together with their clinical colleagues, should be proud of their achievements to date.

Turning to the current joint document, it could be defined as either occurring in the present or modern in style or design[2] and, whilst the document may not be seen as modern, it is probably the greatest acknowledgement of the present picture of skills mix as implemented in the significant majority of UK departments of clinical imaging. The sad fact is that only a small number of departments have made major changes in the clinical imaging team whilst the majority have tinkered with smaller scale changes, in particular the development of assistant and advanced practice roles, although not necessarily in a cohesive or joined up manner.

Radiographers will always, rightly, aspire to change the way they deliver services to ensure the best quality of care for patients and what this document does do is recognise the need to change services. What it does not do and, unfortunately so for the many who would wish it, is dictate an implementation plan for skills mix nationally. This is not the function of the document and neither, many would argue, is skills mix something that should be dictated nationally. Rather, the current joint document seeks to promote a 'whole system' review of services locally to develop them to meet the needs of the organisation, health community, or region. This is combined with advice on the sustainability of services, particularly in relation to succession planning.

What the document also does is recognise some of the changes that have taken place in provision of services, with acknowledgement that radiographers are providing 'medical advice and interpretation', a major change since previous documents, albeit in the context of ensuring appropriate protocols are in place.

I believe we have to take heart from the content of the document and I know this may be perceived as a platitude. Skills mix is here to stay and this document acknowledges that; it also recognises that changes in the current model of service provision are necessary to meet the future challenges.

And challenges we do, indeed, face, with the pressures of 'targets' and 'standards' as well as aspiring to meet best practice expectations and the accreditation of departments in the future. To meet these, it is clear that radiology departments must move from the traditional hierarchical model to a team approach, where the potential of all staff is realised and achieved.

As one of the first consultant radiographers, I can sympathise with Richard's frustration that this role, amongst all others, was not mentioned. However, the fact is that there are still only 23 in post, including two trainee consultants. This is the truly disappointing fact, not their omission from a joint colleges' document. Richard is right to recognise the autonomy and responsibility of the consultant role, but this can be seen as a challenge to radiologists and to radiographers and managers alike. There is recognition that the consultant radiographer role is gaining ground nationally, providing not only clinical services, but clinical leadership, once seen as the sole territory of the radiologist[3]. It is only by sharing experiences and demonstrating potential that we may see the flourishing of the clinical pinnacle of the radiography profession.

As the current document states, the challenge of skills mix implementation needs to be faced at a local level through service reviews and business planning. The Society and College of Radiographers has a role in producing advice and support for managers and staff in developing, not only the consultant radiographer role, but other roles too, to ensure that services are sustainable and fit for the 21st century.

So what of the future? Radiographers must continue to challenge current structures through dialogue both with radiologist colleagues and with other colleagues in the multiprofessional teams in which we function. It is entirely possible, indeed probable, that the greatest opportunities lie in developing new services which cross professional boundaries – and those boundaries may well not be radiologist-radiographer ones. Maybe then we will be able to present a truly modern view on skills mix in which current aspirational practice is accepted by everyone as widespread and current.

References

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