MPEC 18

18th - 20th September 2018
York Racecourse

Abstracts
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Tuesday 18th September 2018

Tuesday 18th September, 09.30 – 10.30

**Keynote Session: Innovation**

The commercialisation of a new medical device that incorporates a novel quantum interference magnetometer
Prof Gary Green, Chief Technology Officer, York Instruments Ltd

In late 2015 a prominent Canadian Ice Hockey player asked on radio why concussion in sports players was so poorly managed. In particular he asked why no one could give objective advice about whether brain function had been affected by a physical blow and whether it had recovered. This led to a small consortium being formed to see if this problem that affects 2.8 million US people a year could be addressed. They discovered that magnetoencephalography (MEG) could be used to record the magnetic fields associated with brain electrical activity and that increased slow wave activity was a feature of a concussed brain. They formed a company, York Instruments in the UK, to build a new MEG scanner that could detect these slow waves and also the abnormal activity associated with many neurological and psychiatric conditions. But previous MEG devices used liquid Helium to cool down SQUIDs (superconducting quantum interference devices) which were then used as very sensitive magnetometers. Liquid helium is in increasing demand and is becoming expensive; most use is not recycled and it is not globally available for the once weekly refills of the MEG scanner. SQUIDs have poor performance at low frequencies.

In this talk I will describe how a new scanner was designed and built; which does not use liquid Helium and exploits a new type of quantum interference device that exploits Andreev reflections between a superconductor and a non-superconducting metal to provide ultra sensitive magnetometry at very low as well as at very high frequencies. The, not straight, path from first employees in 2016 to product in 30 months will be illustrated by lessons learnt.

The future of biomagnetometry will also be discussed and the opportunities for making new products and markets outlined.

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Celebrating 70 years of Collaboration, between the NHS, Industry and Academia

Paul Gaudin, CEO, Tutella Ltd

Paul will be speaking on his career in innovation and the challenges and opportunities posed by the rapidly changing and digitally informed health consumer, for the NHS, Academia and Engineering

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Tuesday 18th September, 11.00 – 12.00

**Medical Physics Professional Session**

**MPE – a new Regulatory Council?**
Dr Niall Macdougall, IPEM MPE Working Party

*Awaiting abstract*

**MPACE Accreditation for your department**

Supplied by Compton D.

*Supplied by United Kingdom Accreditation Services (UKAS), UK*

As the UK’s National Accreditation Body, UKAS has been appointed to manage and deliver the accreditation of Medical Physics and Clinical Engineering (MPACE) services. In July 2017, a UKAS pilot
assessments programme was announced. As presented at last year’s conference the pilot is using BS 70000 as the criteria for assessment and accreditation and will include two service areas (Radiotherapy Physics, Clinical Engineering – management of medical devices). For areas outside the scope of the initial pilot areas, UKAS is now working with the relevant experts in the different fields to develop the accreditation scheme in readiness for their inclusion after the pilot activities have been completed.

This presentation will provide an update on the development of the UKAS accreditation programme. It will re-consider the links between certification standards and the process of accreditation and the implications for Medical Physics and Clinical Engineering services. It will highlight areas of the standard (BS 70000) where Services in the pilot scheme have identified gaps against the current management systems. It will also provide some indication as to the potential evidence required for MPACE department to demonstrate compliance and competency against the standard. Finally, it will provide an overview of the assessment approach being adopted to demonstrate the competence and compliance of a number of Services involved in the pilot.

For up to date information on the MPACE project please refer to:

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**Tuesday 18th September, 11.00 – 12.00**

**Engineering Professional Session**

**The Engineering Standards Review**

Katy Turff, Head of Professional Standards, Engineering Council

The Engineering Council is the UK regulatory body for the engineering profession. We hold the national registers of 222,000 Engineering Technicians (EngTech), Incorporated Engineers (IEng), Chartered Engineers (CEng) and Information and Communications Technology Technicians (ICT Tech).

In addition, the Engineering Council sets and maintains the internationally recognised standards of professional competence and ethics that govern the award and retention of these titles, as the UK Specification for Professional Engineering Competence (UK SPEC) and the ICT Tech Standard. This ensures that employers, government and wider society - both in the UK and overseas - can have confidence in the knowledge, experience and commitment of professionally registered engineers and technicians.

UK-SPEC is supported by complementary documents setting out requirements for accreditation of Higher Education Programmes and approval of Qualifications and Apprenticeships. The requirements for Professional Engineering Institutions implementing the Standards are set out in the Registration Code of Practice.

This suite of documents is reviewed every five years and the 2018 review is now in progress. The Engineering Council is seeking input from a wide range of stakeholders. This session will introduce the key themes and format of the review, how it fits with the Engineering Council’s strategic plan, and outline the approach to consultation. Delegates will be encouraged to contribute feedback on the current standards documents and their thoughts on how these may need to develop to ensure they continue to meet the needs of the profession.

**Engineering Better Care**

John Clarkson
Professor of Engineering Design, University of Cambridge Director, Cambridge Engineering Design Centre

Over the past two decades, there have been numerous references to the value of a systems approach in calls to transform health and care, without there being a common understanding of what this might mean. However, many people working to improve health and care are aware of and use systems techniques, leading to improved pathways, processes and patient experience in many areas. Healthcare leaders know
intuitively that there is a need to involve stakeholders in decisions, think across pathways and deliver integrated care, but lessons can be learned from the analysis and rigour applied in complex engineering systems.

A unique project, based on an extended conversation within a forum of systems engineers, health and care professionals, quality improvement experts and patient representatives, will be described. This work, led by the Royal Academy of Engineering, in collaboration with the Royal College of Physicians and the Academy of Medical Sciences, brought together ideas from engineering and health and care to define a new framework for improvement. Engineering better Care – a systems approach to health and care design and continuous improvement will be described as a standalone set of questions, with reference to systems, design, risk and people thinking. The talk will conclude with reflections on the value of developing the questions and ways of thinking into ways of doing and highlight some of the opportunities and challenges ahead.

Tuesday 18th September, 11.00 – 12.00

**Technologists Professional Session**

**Medical Device Driving Licence**
Paul T. Lee
Medical Devices Training Manager at ABM University Health Board, Morriston Hospital, Swansea
Chairman of NAMDET UK

It’s been over 10 years since the Medicines and Healthcare products Regulatory Agency (MHRA) designed and launched an elearning programme called the Medical Device Driving Licence (MDDL) and Paul's talk will look at where this training currently sits and how this can be accessed for free and used in clinical and medical device training programmes. In 2017 the National Association of Medical Device Educators & Trainers (NAMDET  [www.namdet.org](http://www.namdet.org) ) took ownership of the MDDL programme and are now looking to work with industry, healthcare and academia to update, develop and access to this training resource.

IPEM will be a key player in helping to shape the course content and help align with existing training programmes for apprentices, technologists and scientist that work with medical devices in healthcare.

Tuesday 18th September, 14.00 – 15.00

**Leadership Session**

**Developing Healthcare Science Leaders**
Fiona Carragher, Deputy Chief Scientific Officer, NHS England

As the NHS turns 70 we look towards the next era of medicine where advances in technology will fundamentally change the way in which scientific and diagnostic services are delivered. Healthcare Scientists will have a significant role in transforming care and services for patients, from supporting the prevention agenda through screening and early diagnosis to enabling more personalised therapy. As NHS England develops a five year Healthcare Science Strategy the importance of leadership takes centre stage. Who in the NHS has both the clinical expertise and scientific training to contextualise to Trust boards and system partners how advances in, genomics, AI and bioinformatics will impact patient care ? The pace of advance and complexity of technologies creates opportunities for the development of the scientific leaders of the future.
My KTP Experience
Dr Bal Sanghera, Associate on the CSO’s Knowledge Transfer Partnership Programme for Leaders in Healthcare Science

Presenting a personal view of the Inaugural Chief Scientific Officer’s Knowledge Transfer Partnership Associate post with NHS England. Description of project selection, challenges faced during implementation and how to deal with collaboration and tasks. Also an appreciation of King’s Fund training to develop leadership skills that allows one to grow at the national level.

Tuesday 18th September, 14.00 – 15.00
Innovation Session

Why does data matter? Is it all hype, or could it save the NHS?
Keevil SF
Medical Physics Department, Guy’s and St Thomas’ NHS Foundation Trust, UK.

Media coverage of ‘artificial intelligence’ (AI) has increased dramatically in recent years, and the context of these stories is often healthcare. Expectations are rising among the public, and also among healthcare managers and professionals amidst claims that ‘AI may be the thing that saves the NHS’ (1). Medical imaging has been a particular focus of attention, with one eminent computer scientist recommending that we ‘should stop training radiologists now’ (2), because AI will soon do a better job of image interpretation.

Healthcare data certainly poses problems that require radical solutions. It is estimated that in 2011 the US healthcare system collected $150 \times 10^{18}$ bytes of patient data, far exceeding the capabilities of conventional management, processing and interpretation. To give a concrete example, in a single cardiac MRI examination it is now possible to acquire not just structural images, but also images reflecting various aspects of tissue biophysics, physiological and mechanical function, amounting to tens of gigabytes of data. When data from other imaging and from clinical assessment, patient monitoring, clinical measurement and genomics is added in, the scale of the issue becomes clear. Despite use of picture archiving and communication systems (PACS) to improve clinical workflow in imaging departments, there are growing problems with radiologist workload and reporting backlog, with the potential to impact on metrics and more importantly on the quality of patient care.

So use of AI in medical imaging is in part driven by necessity, in the face of an unmanageable deluge of data, but the potential is far greater. AI can find patterns in image data that are not perceptible by human radiologists, raising the prospect of redefining diseases and optimising treatments on the basis of imaging phenotypes (an emerging field known as radiomics).

At the same time, Richard Waters of the Financial Times has recently cautioned against over-hyping AI (3). He points out that while AI may have huge predictive value, it lacks the human ability to reason abstractly: to find uncommon but important things, exceptions to the usual rules. AI is currently at the peak of the ‘hype cycle’ (4), a well-known phenomenon in the context of emerging technologies when early promise, fuelled by exaggerated media coverage, leads to raising of expectations to an unsustainable and unrealistic level. The risk is that when reality bites the resulting disillusionment, loss of enthusiasm and consequently of funding frustrates the real opportunities that a technology has to offer. There is a need for balance, to moderate current expectations without discounting potential longer-term benefits.

This talk is written from the perspective of a medical physicist trying to advise a large NHS organisation on these issues. I will define some basic terms and present some case studies from the literature to illustrate the potential, but also some of the pitfalls and challenges that mean AI is not the panacea it superficially appears to be. I will venture opinions as to what the NHS needs to do to take maximum advantage of the opportunities that AI presents, in terms of research, health technology assessment, workforce, and long-term strategic vision.

(1) Professor Sir John Bell, BBC News website, 2nd January 2018.
Deep Learning in Cardiac MRI
Nick Byrne, Guy's & St Thomas’ NHS Foundation Trust

Congenital heart disease describes a range of structural abnormalities affecting the heart’s chambers, valves or major blood vessels that are present from birth. A full, 3D understanding of patient-specific anatomy is critical to the care of these patients. Increasingly, doctors are looking to advanced forms of presentation (such as 3D printing, holography or virtual reality), for the visualisation of 3D medical image data.

Despite the potential of these technologies, their uptake remains hampered by laborious and technically challenging image pre-processing. This task can be pre-requisite to the optimal use of these technologies. Our work is exploring the use of deep learning approaches to the segmentation of cardiac magnetic resonance (CMR) images.

Deep convolutional neural networks (DCNNs) are rapidly becoming the foundation to many tasks in medical image processing. In particular, DCNNs have outperformed conventional image processing approaches in the segmentation and measurement of ventricular volumes in CMR images. The ability of DCNNs to learn abstract representations from images makes this approach robust to the variation in anatomy and image quality that is observed in the clinic.

Here we present our initial results of using a deep, fully convolutional architecture with dense 3D kernels to perform this segmentation task.

Accelerating Artificial Intelligence In Health and Care
Melissa Ream, Future Foundations

How much of what is said about AI in use in health and care today is reality and how much is hype? In this relatively new arena, what evidenced-based solutions are currently out there in use and what developments are in the pipeline? How can we catalyse the growth of an ethical market in health and care that offers solutions that are safe, effective and offer value, to citizens, the health and care system and to society?

Highlighting the results of the recently published state of the nation report, "Accelerating Artificial Intelligence in health and care", this session will look at the live map of organisations using or planning to use AI and will examine some of the compelling use cases and areas exhibiting early potential for disruptive innovation. It will also explore solutions necessary to build a sustainable AI ecosystem across health and care.

Tuesday 18th September, 14.00 – 15.00

Patient Assessment Skills Session

Patient assessment skills session
Mark McDade, Senior Clinical Technologist, Glasgow

Patients in hospital are often at risk of becoming acutely ill. Unfortunately, there is a body of evidence showing that the recognition of deteriorating health by staff is often delayed or managed inappropriately resulting in late treatment, avoidable admission to ITU and unnecessary deaths. Clinical Technologist, Scientists and Engineers have a defined duty of care. Grounds for HCPC registration to be revoked include failing to complete an accurate patient assessment and responding to its findings competently. Similarly Clinical Technologists are expected to comply with the Academy of Health Care Science Good Scientific
Practice which explicitly expects them to perform competent clinical assessments. This session will provide the necessary standardised tools to fulfil these competencies with confidence.

**Tuesday 18th September, 16.15 – 17.00**

*Plenary Session: Woolmer Lecture*

Prof Alison Noble, University of Oxford

*Awaiting abstract*
To mark the centenary of end of World War 1, it is appropriate to recall the impact of that war on those aspects of medical technology that now fall within the scope of Medical Physics and Bioengineering. Front-line radiology required field equipment. Mobile x-ray units were deployed at casualty clearing stations, supporting assessment and emergency surgery. The design of these mobile imaging systems developed slowly, responding to the front-line needs. The need to remove bullets and shrapnel drove the development and use of a range of x-ray localisation techniques, including the Hertz Compass, precursor of stereotactic surgery. Widespread use of diagnostic x-rays emphasised the need for radiation protection, many radiographers suffering from radiation damage to hands and neck, and a variety of blood disorders. 1914 marked a peak in mortality of those new radiological workers whose subsequent death resulted from exposure to radiation. Electrotherapy, well established before the war, was widely used. Interrupted electrical stimulation aided recovery from partial paralysis. Ionic therapy was used to promote topical treatments using a variety of drugs. Surgical diathermy and high-frequency medical diathermy were both in use. Electro-diagnosis was used to determine the extent and cause of paralysis and sensory loss, and to distinguish ‘malingersers’ from the truly injured. Improved prosthetic limbs were designed, particularly for the upper limbs, using newly available alloys and polymers for lightness. WWI resulted in numerous medical scientific and technical developments and, more specifically, widened the acceptance of technology as an integral part of medical practice, and the need for skilled scientists and engineers in its design and use.

IOMP International Project “History of Medical Physics” – First Results
Slavik Tabakov
King’s College London, London, United Kingdom. IOMP, York, United Kingdom

The history of the International Organisation for Medical Physics (IOMP) spans over 50 years. During this period IOMP has collected information from medical physics societies worldwide. This allowed for gradual mapping of the global development of the profession – currently with c. 26,000 medical physicists in 86 countries. In order to have sustained growth of the profession and to face the challenge of tripling the current global number of medical physicists by 2035 [1], IOMP launched in 2016 a large international project “History of Medical Physics”. The project will trace the professional development in various countries, showing specific models which could be useful for other countries aiming to expand their medical physics workforce and its place in healthcare.

The project will not only focus on the professional development: it will also trace the development of the sub-divisions of medical physics (starting with the discovery of X-rays, which was soon followed by the first appointment of a medical physicist). This way the project will create a Compendium of independent Volumes/Parts, which will reflect the main areas of development of medical physics, including: Diagnostic Radiology (X-ray) Imaging; Computed Tomography; Radiotherapy (External beam); Radiotherapy (Brachytherapy); Nuclear Medicine Imaging; Ultrasound Imaging; Magnetic Resonance Imaging; Optical Systems and NIR in Medicine; Medical Informatics; Radiation Measurement and Protection in Medicine; Professional Development; Education&Training Development. Each of these parts will be published as Special Issue of the IOMP Journal Medical Physics International [2].

The presentation will highlight the important moments of the first ready chapters: Professional Development; Education&Training Development; Diagnostic Radiology (X-ray) Imaging. The completed Professional Development chapters show the professional activities in three of the IOMP Regional Federations – the growth of their workforce, education/training, etc. The completed Diagnostic Radiology chapters are related to History of X-ray tubes and the first Receptors (Radiographic Films and Film-Screen
The project “History of Medical Physics” will span over many years. Its results will be a very useful source of information for the development of the profession; the development of various equipment and methods; the colleagues who have invented and introduced these, etc. More importantly the project results will be a written proof of the significant role played by medical physicists in contemporary medicine.

References:

Wednesday 19th September, 11.00 – 12.30

Industry Session: Generating Health and Wealth for the NHS Through Innovation

Clinical evaluation of a novel algorithm in the detection of epileptic seizures
Ruth Brotherstone, NHS Lothian. Mayur Patel, PA Consulting

Aim: To clinically evaluate a novel algorithm based on percentage changes in heart rate and oxygen desaturation in the detection of clinically significant epileptic seizures.

Background: In the UK, one person in 50 will develop epilepsy at some time in their lives with approximately 82 people being given the diagnosis of epilepsy each day resulting in 420,000 people having some form of active epilepsy at any one time (www.parliament.uk). Official statistics report around 1000 deaths due to epilepsy in the UK each year (Hanna et al 2002). It is believed that some seizures resulting in death could have been avoided if someone had been alerted to the seizure and intervened with rescue medication and body re-positioning to prevent an obstructed airway. (Langan et al 2000)

A novel algorithm invented by Brotherstone (NHS Lothian, U.K patent) in collaboration with BioQuarter business partners was incorporated into two prototype devices designed by PA Consulting and trialled in Edinburgh between January 2015 and December 2017 at Royal Hospital for Sick Children and Western General Hospital was funded by Edinburgh & Lothian Health Foundation.

Methods: 116 consenting participants were recruited who had planned electroencephalographic videotelemetry (VTEM) at the Royal Hospital for Sick Children and Western General Hospital, Edinburgh. Device data was synchronised to the VTEM system via the hospital server. Seizure types were classified into clinically significant and clinically insignificant seizures and compared to normal physiological events e.g coughing, sneezing, arousal, turning over in bed etc and identified on VTEM. Device data was used at those identified times to calculate optimal trigger levels and calculate sensitivity and specificity to respond to true positives of a clinically significant seizure and to minimise the number of false positives generated by normal events.

Results A total of 575 seizures were identified on Electroencephalographic Videotelemetry. Data from the novel algorithm devices were analysed at these times and compared to data during 2586 normal physiological events. Analysis is pending. Pilot Study Results: 527 seizures were analysed for the total seizure group p<0.001. Absences (36), complex focal (102), frontal lobe seizures (229), generalised tonic-clonic seizures (11), myoclonus (28), temporal lobe seizures (31) and tonic seizures (90) were identified and compared to a range of 496 normal physiological events. Diagnostic testing results were calculated for generalised tonic-clonic seizures with sensitivity of 88% and specificity of 85% for percentage heart rate change at a specific trigger level. Clinically significant seizures gave a sensitivity of 79% and specificity 75%. When one/ other/ both parameters were diagnostically tested an improved sensitivity of 91% was achieved with a specificity of 75%.
Conclusion: Percentage heart rate change and oxygen saturation can be used as reliable indicators of seizures when set at specific levels and can distinguish clinically significant seizures especially generalised tonic-clonic seizures from normal events.

MRI Planning in Radiotherapy
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There is an increase in interest and utilisation of MRI in radiotherapy treatment planning due to the superb soft tissue contrast afforded by MRI compared to CT. This enables more accurate and consistent delineation of the tumour and organs at risk which is currently the largest source of uncertainty in the radiotherapy process. The use of MRI for tumour delineation also has the potential to increase patient access to radiotherapy treatment and deliver a curative treatment for patients who previously were not eligible for radiotherapy.

Conventional CT-MRI registration techniques suffer from errors due to misalignment of the independently acquired image sets and differences in patient set-up and anatomy which reduces the benefit of the MRI acquisition. MRI-based planning offers a solution to these errors by acquiring all the image information required to plan and treat the patient in a single MRI imaging session.

Conventional CT-MRI planning approaches rely on the electron density information contained in the CT acquisition to provide a model for accurate dose calculation. An MRI-based pathway requires creation of a dose calculation dataset which is derived from the MRI image – a synthetic CT. There is good evidence of the dosimetric suitability of a number of synthetic CT options. However, there is only a small number of CE marked solutions, and dosimetric equivalency is only part of the requirements needed to clinically implement an MRI-based process without the accompanying CT.

This presentation will describe the Newcastle experience of introducing MRI into a CT-based planning process, and the evolution towards an MRI-only pathway. Newcastle commissioned their first MRI-simulator in 2009, introducing MRI-CT image fusion for delineations in prostate, gynaecological sites, brain, head and neck, anus and rectum patients. Our experience in the interpretation of MRI images, combined with the clinical frustration triggered by the errors in registration and the delineation compromises that this causes, has motivated us to work towards an MRI-based planning pathway, initially for prostate patients.

The collaboration with industry partners has played a crucial role in this development. In particular, the research agreement with Spectronic Medical has enabled us to evaluate a synthetic CT solution and develop a more rigorous geometric distortion testing programme using their phantom and automated analysis software.

A key consideration for implementing an MRI-based planning process with a conventional X-ray Image Guided Radiotherapy (IGRT) treatment machine is the selection of an appropriate reference image to enable image matching prior to treatment delivery. Ongoing work to compare the treatment verification options with several reference image types will also be described.

Filling ‘the translational gap’ – funding to build bridges
Mayur Patel, PA Consulting

The disconnect between clinical/scientific research and the translation of the research into clinical practice is called the ‘translational gap’. A report published by Quality of Health Care in America, 2001, suggested that it takes an average of 17 years from new knowledge generated to be incorporated into practice. The governments across the globe have launched various initiatives since then. The UK government set up National Institute for Health Research (NIHR) in 2006 under the government strategy for health research to transform research in the NHS. PA Consulting has collaborated with NHS Trusts to bridge the translational gap by taking early ideas to concept/prototype building to clinical investigation and commercialisation of the developed technology.

In the NHS / academia, clinicians and academics are excellent at identifying unmet needs. However, these
needs are not enough to gain interest from the industry as they are far from the market and commercial benefits are not clear or tested at this point. They need to be converted into early prototypes / concepts to prove their functionality. There are numerous aspects which are responsible for the translational gap and they vary from one country to the other, one institution to the other.

These factors are:

Justification: It is important to use money wisely on the needs/ ideas which provide the maximum value to the patients. This requires knowledge of the market, understanding of the requirements related to technology and aspects about manufacturability. This information is not often easily accessible within the NHS which makes it difficult for clinicians to decide which ideas to take forward.

Resources/ technology: The unmet needs require solutions which could be in the form of software, materials, coatings, mechanical assembly, electronics, communication module to an app. It is not feasible for the NHS to have the relevant skills and facilities available in-house unless there is a significant portfolio of such opportunities which can generate revenue for the Trust.

Regulatory: the regulatory burden has increased in the recent years. There were many medical device companies in the late 20th century started commercialising devices from 'sheds' or 'garages' which is not the case anymore.

Funding: One of the key factors is funding - it is difficult to get internal funding in the NHS even if it is for a ground-breaking innovation as its main aim is to deliver health to the patients. The NHS is already struggling with the shortfall of funds for running the standard clinical services so getting funds for research and development is challenging.

We explain models where some of these hurdles can be overcome, through

- identifying unmet clinical needs that can generate revenue for NHS Trusts
- applying for funding opportunities through government funding (NIHR), venture capital, angle investors and corporate funding
- designing and developing concept technologies/ devices as per the required regulatory framework
- licensing developed technologies to commercial companies through exploiting our industry network

### Invention for Innovation (i4i) funding

*Allen, L.M.*

National Institute for Health Research (NIHR) Central Commissioning Facility

This talk will present a summary of the NIHR’s Invention for Innovation (i4i) funding programme that supports translational research on medical devices and diagnostics. NIHR accepts i4i applications for projects led by SMEs, academic institutions and NHS Trusts. The talk will include a summary of the scope of the funding programme, an overview of the different funding streams that are available, tips for writing a successful application and dates for the current round of calls.

Further information can be found at the website shown below or by contacting i4i@nihr.ac.uk
Imaging the Aging Brain
Dr Roger Staff, NHS Grampian

Brain aging is inevitable, but not uniform; it affects everyone, or every brain, differently. Even among healthy individuals brains acquire different levels of atrophy, different degrees of vascular change and other pathologies. The ultimate elixir of eternal youth would slow brain ageing down or stop it altogether. Is the slippery slope inevitable? Or are there steps we can take to reduce or brain ageing, hopefully leading to a healthier, happier and longer life? In this talk I will describe the ageing birth cohort imaging findings and described the characteristic, genetic and environmental that are correlated with health ageing.

A Study of Dynamic Collimator for SPECT/Gamma Camera Image Quality Improvement
Julian Liu¹, Aysha Luis², Steve Nguyen¹
¹Cancer Centre London, London, United Kingdom. ²Nottingham University Hospitals NHS Trust, Nottingham, United Kingdom

Introduction
The standard collimators used for SPECT consist of hexagon holes. The size of these vary in radius, septal thickness, and depth in order to optimise for spatial resolution, sensitivity, energies of the isotope being used and efficiency of data acquisition. There are some limitations however, causing local inconsistencies, aliasing, inefficiency and loss of information.

In this study, a dynamic square collimator is proposed, whereby the signal detection area is evenly distributed, mathematically described and applicable for post processing. This eliminates the problems of alias and sampling uniformity, and results in significant improvement in signal to noise ratio (SNR) and spatial resolution.

Methods
Two collimator models were developed. In the first, the septal thickness was equal to the side length of the square of the hole. In the second, the septal thickness was halved. A fourth of the detector surface area of the first model was exposed to radiation through the collimator holes, while the second type specified four ninths.

The proposed collimator was designed to ensure even exposure of the detector surface, covering four and nine positions for models one and two, respectively.

The movement of the collimator can sometimes cause the camera to vibrate. This can be overcome by a zero-external-force design, in which the first structure consists of four symmetrical parts while the second structure contained an extra device to counteract the external force.

The resolution is determined by collimator type, hole size, and distance between the collimator (effective) and the detector surface. In the first structure, the maximum distance was the effective length of the collimator hole. This was halved for the second structure.

A mask equivalent to the collimator grid was applied during data acquisition to reduce the signal inaccuracies and improve the resolution and SNR. The removed measurement can still be useful as a reference of the uptake distribution in the case of weak activities and where the sensitivity is reduced.

Results
The process of SPECT using the first collimator structure from a point source was simulated. The side length of the square of the hole: 4 mm; the length of the holes: 20 mm; the minimum distance between the
point source and the collimator: 100 mm; the distance between the point source and the centre of rotation (COR): 70 mm; the distance between the collimator and the detector: 20 mm.

Conclusions and discussions
The dynamic collimator allows all the detecting units to be evenly exposed to radiation, thus eliminating alias and significantly reducing noise. The post processing of the acquired data/image improves the focus of the point spread function as well as providing optional specifications of the collimator. The two types were designed to optimise the sensitivity and spatial resolution, and to meet a wide range of clinical requirements. The septal thickness was determined by the energy of the isotope, which defines the highest spatial resolution.

Comparing the effectiveness of CT metal artifact reduction software on aortic stents
Esther Uwannah
King's College University, London, United Kingdom. Royal Free London NHS Foundation Trust, London, United Kingdom

Background: Endovascular aortic repair (EVAR) is now the leading form of intervention for abdominal aortic aneurysms[1]. Post-surgery, leaks within the vasculature can occur. To assess whether an endoleak has taken place, current protocol requires postoperative imaging using Computed Tomography (CT). However, fenestrated EVAR stents contain many small pieces of gold for positioning under fluoroscopy. Since gold is highly dense in comparison to tissue, this can result in severe metal artifacts[2], which could obscure the information needed for an accurate diagnosis.

Objective: To determine which CT scanner within the Trust is most able to reduce the effects of metal artifacts, improving diagnostic accuracy and patient outcomes.

Methods: A water phantom containing a model aorta with an aneurysm was designed, and an fEVAR stent was inserted. The phantom was imaged using three CT scanners within the Trust: 1. GE Discovery 750 HD; 2. Toshiba Aquilion ONE; 3. Toshiba Aquilion PRIME SP, both with and without each manufacturer’s method of metal artifact reduction. This includes GE Gemstone Spectral Imaging (GSI) and GSI + Metal Artifact Reduction Software (MARs), and Toshiba Single Energy Metal Artefact Reduction (SEMAR). The mean Hounsfield Units of the water surrounding the aorta was measured along with its standard deviation for each slice of the phantom containing the fEVAR stent, using an IQWorks analysis tree, in order to give a quantitative measurement of the effectiveness of the metal artifact reduction (MAR) method.

Results: With a CTDIvol of 15.02mGy, GE’s GSI + MARs at 140keV (b) reduced the mean standard deviation of HU by 42.6% from the standard Triple Phase Aorta protocol (c), with GSI at 140keV alone (a)
reducing the standard deviation by 51.9%. SEMAR on the Toshiba Aquilion ONE led to a 7.13% reduction (ROI 20), and a 9.60% reduction (ROI 40) at 15.6mGy CTDIvol. SEMAR on the Toshiba Aquilion PRIME SP increased the severity of the metal artifacts, with the standard deviation increasing by 3.45% when dose modulated, and 2.73% for fixed mAs. However the difference in mean standard deviation of HU for the fixed mAs protocol (M=18.5, SD=5.47) and the SEMAR fixed mAs protocol (M=19.0, SD=4.92) conditions; t(70)=-1.797, p=0.076, was not found to be significant using a paired student t-test.

Figure 1: (a) GE’s GSI 140keV; (b) GSI + MARs 140keV; (c) no MAR

Conclusions: The GE Discovery 750 HD’s GSI reconstruction at 140keV (a) was found to be the most effective MAR method. However, this method uses dual energy acquisition and therefore results in a higher dose to the patient than the current protocol. The benefits of reduced metal artifacts for patient diagnosis should be weighed against the increased radiation dose before a change in protocol is actioned.

Key References:

Retrospective study of extracardiac uptake in myocardial perfusion imaging
Thomas Biggans, Glen Gardner
NHS Tayside, Dundee, United Kingdom

Objective
Following the removal of Dipyridamole from the market the author’s department began to use Regadenoson as the stressing agent for myocardial perfusions imaging (MPI). The objective of this work was to quantitatively establish the relationship between the amount of extracardiac activity within the field of view (FOV) on myocardial perfusion imaging and four parameters: stressing agent, time between injection and imaging (uptake time), use of arm exercises and BMI.

Method
Reconstructed short axis images of 75 patients were gathered from three patient groups (Dipyridamole (with Arm Exercises), Regadenoson (No Exercises) and Regadenoson (with Arm Exercises)). Regions of interest were drawn around the myocardium and background region to obtain a ratio of myocardium to extra-cardiac activity.
Results
Correlation coefficients showed that there was no significant linear correlation between the uptake time (-0.15) or patient BMI (-0.01) and extra-cardiac activity. Arm exercises significantly (p=0.01) reduce extra-cardiac activity in the FOV for patients stressed with Regadenoson. There was a significant difference (p=0.04) between the Dipyridamole (with arm exercises) group and the Regadenoson with arm exercise group. No significant difference (p=0.22) was found between the Regadenoson without exercise group and the Dipyridamole with arm exercises group.

Conclusions
The switch to Regadenoson did not significantly increase the amount of extra-cardiac activity in the FOV. Uptake time is not a critical factor in maintaining a low level of extra-cardiac activity in the FOV. The patient's BMI cannot be used as a predictor of extra-cardiac activity in the FOV. Asking patients to perform arm exercises does significantly reduce the amount of extra-cardiac activity in the FOV when using Regadenoson as stressing agent. Therefore it is justifiable to ask patients to perform arm exercises as although it may no longer benefit them in terms of side effect reduction it does benefit the patient with a reduction in the likelihood of a repeat acquisition being required.

Image guidance and Therapy with Ultrasound Random Phased Array
Muhammad Zubair, Robert J. Dickinson
Imperial College London, London, United Kingdom

Objective:
Randomized phased arrays have been used for generating and steering single focus and multiple foci with low levels of grating lobes due to the breakage of periodicity of the elements and are considered as useful source of HIFU. However, the reliance of HIFU on MRI for real time visualization of the targeted tissue is a major constraint in its clinical use due to the high cost of MRI and its low temporal resolution. There is a need to study the imaging capabilities of a therapeutic random phased array transducer for guiding the treatment process.

Method:
Dual mode ultrasound phased arrays would have the advantage of using the same array for both therapy and imaging due to the inherent registration between imaging and therapeutic frames of reference. The random spherical array would have limited field of view due to the fact that the array is optimized for therapy only and has large, directive elements sparsely positioned on a spherical surface. Nevertheless, images obtained will be useful for directing therapy as they will be perfectly aligned with the therapy transducer. Since strong scattering objects in path of HIFU beam are also in path of imaging beam, such scattering objects can be detected in real time and the HIFU beam can be adjusted accordingly. In our HIFU system the elements are randomly distributed with inter-element spacing much more than the required half a wavelength for reduced side lobes (Hand et. al. 2009), thus the spatial resolution of this
system is poor. However, we use synthetic aperture imaging technique which has the potential to improve the spatial resolution of the random phased array. The simulations were carried out in MATLAB. The numerical results were performed for a 1 MHz 256-element random phased array, made by Acublate Ltd, London, UK. Simultaneous foci were generated in simulations as well as experimentally based on the theory described by Gavrilov and Hand (2000a).

Results:
For imaging, preliminary simulations of synthetic aperture imaging with a 1MHz 256 element random phased array are shown. In fig.2, grey scale image of a wire target array is shown, which is a composite of different point spread functions (psfs). The axial spacing between two wires is 10 mm, whereas the lateral distance is 5mm. The -6 dB full width half maximum of the focused psf is 1.6 mm. The array was integrated with the verasonics system to acquire raw data. Three metallic balls of diameter 7mm immersed in water bath with lateral and axial spacing of 10 mm were imaged. Initial results were encouraging and signals the potential of imaging with the random phased array system.

Conclusion:
Simulation and experimental results show that random phased array is capable of therapy producing multiple simultaneous foci as well as image guidance. The use of synthetic aperture imaging techniques makes it possible to image with the array with improved resolution.

Wednesday 19th September, 11.00 – 12.30

Radiotherapy and Protons

Making proton therapy a part of NHS radiotherapy
Dr Ranald Mackay, The Christie NHS Foundation Trust, Manchester

Professor MacKay will outline progress toward commencing treatment with proton therapy at The Christie. In particular the talk will examine the responsibilities of The Christie, the equipment manufacturer and the build team in delivering the £125m project as well as examining where proton therapy fits into an advanced radiotherapy service. As final preparations are made for the commencing treatment it is an opportune time to review the key steps in introducing a complex and sometimes controversial new therapy to the NHS.

The CoBra Project to Develop an MRI-Guided Robotic Biopsy and Brachytherapy System
Antony Palmer, Wojciech Polak, Sarah Wilby, Dominic Hodgson, Yoodhvir Nagar, Matthew Gummerson
Portsmouth Hospitals NHS Trust, Portsmouth, United Kingdom

The CoBra (Cooperative Brachytherapy) project aims to develop an innovative technology for robotic biopsy and brachytherapy under MRI guidance. The five year project commenced early 2018 and is funded by EU Interreg 2 Seas, involving institutions from the UK, Belgium, Netherlands and France, led by the University of Lille. The project aims to improve the quality of both diagnosis and treatment of localized cancers, initially in the prostate with potential applications for other sites. The main deliverable will be a robotic arm for both biopsy and brachytherapy treatment (LDR and HDR), utilising a single perineum puncture needle technique, with high precision and accuracy under real-time MRI guidance. The robotic arm software development includes dedicated software responsible for needle and organ motion tracking under MRI, automatic dose optimisation and real time treatment delivery monitoring. A geographic mapping of patient need will also be undertaken.

Brachytherapy may be further developed to improve accuracy, reliability, and the adoption of recent advances in focused and focal approaches. A single system to improve the effectiveness of biopsy and the accuracy of brachytherapy treatment, utilising exact knowledge of tumour location via real time MRI can reduce uncertainties. Current state-of-the-art, utilising MRI-ultrasound fusion biopsy is time and resource consuming. It is envisaged that biopsies can be performed with an automated robot under MRI guidance in real time saving staff and theatre resources and improving accuracy.
An introduction to the project, the scope and milestones, and progress to date, will be outlined.

An IPEM affiliated audit of the use of MRI for external beam radiotherapy treatment planning in 2018

Richard Speight¹, Maria Schmidt², Gary Liney³, Robert Johnstone⁴, Cynthia Eccles², Michael Dubec⁵, Ben George⁶, Ann Henry¹, Hazel McCallum⁷

¹Leeds Cancer Centre, Leeds, United Kingdom. ²Royal Marsden NHS Foundation Trust & Institute of Cancer Research, London, United Kingdom. ³Ingham Institute & Liverpool Cancer Therapy Centre, Sydney, Australia. ⁴Guy’s and St. Thomas’ NHS Foundation Trust, London, United Kingdom. ⁵The Christie NHS Foundation Trust, Manchester, United Kingdom. ⁶University of Oxford, Oxford, United Kingdom. ⁷Northern Centre for Cancer Care, Newcastle, United Kingdom

Background

External beam radiotherapy treatment planning is becoming more dependent on MRI derived contours. To facilitate this, MRI vendors are working on enabling patient setups necessitated by radiotherapy treatment. Furthermore, MRI-linacs are commercially available and incorporate MRI directly into the workflow.

In response to these trends, an IPEM working party will report on MRI use for external-beam radiotherapy treatment planning. The scope of this group includes guidance on MRI use for external-beam radiotherapy (EBRT) and how to set up a clinical service. In addition, the working party will audit UK centres on current utilisation of MRI for EBRT planning.

Method

The audit has been developed by the working party and has sections regarding: institution background; MRI equipment and access; which clinical sites MRI is used for and how it is used; MRI to CT registration; commissioning and QA; safety; staffing; and future plans for MRI use. The survey has been piloted in seven centres represented on the working party (six from the UK and one from Australia). It will be distributed electronically to all UK radiotherapy departments with results expected back in 05/2018. The full results will be: presented at MPEC 2018; published in a peer reviewed journal; and used to inform the IPEM working party report.

Results

The results from pilot study have been analysed. These show that access to MRI varies across the seven centres: four have access to a radiology owned MRI scanner modified to allow treatment position scanning; and three have an MRI scanner dedicated to radiotherapy. This access corresponds to only two centres with >10 hours/week dedicated to radiotherapy treatment planning. In terms of the number of scans, two centres image >5 patients/week in the treatment position and three centres scanning >5 patients/week in a diagnostic position (for example, brain scans).

The most common clinical sites for utilising MRI were reported to be: brain/spine (all); H&N/liver (five); prostate (five); gynaecological/pancreas/rectum/anus (four). To utilise MRI all centres registered MRI to CT rigidly with one centre using both rigid and deformable registration.

In terms of QA specific to radiotherapy use, responses varied between centres with the following frequencies reported: daily (three); weekly (two); monthly (five); quarterly (one); biannually (two); and annually (four). One centre has no radiotherapy specific QA for its MRI scanner.

When looking to ambitions for MRI use within the next five years: three centres intend to use functional MRI; three centres intend to purchase a dedicated MRI scanner; four intend to use MRI-only radiotherapy planning; and two intend to purchase a MR-linac (three already have access).

Conclusions

An audit has been designed to assess the use of MRI for EBRT treatment planning, the results of which will inform an IPEM working party report. It has been successfully piloted in seven centres and the results demonstrate varied access to and use of MRI across the centres included. The survey will be sent to all UK radiotherapy centres with results to be collected by 05/2018.
Indirect MRI Planning for prostate external beam radiotherapy without the use of implanted fiducials
Isabel Palmer\textsuperscript{1,2}, Christopher Thomas\textsuperscript{1,2}
\textsuperscript{1}King’s College London, London, United Kingdom. \textsuperscript{2}Guy’s and St Thomas’ NHS Foundation Trust, London, United Kingdom

**Objectives**
The aim of this study is to assess the feasibility of the integration of MRI into the prostate radiotherapy planning pathway. This includes quantification of the inter-clinician and inter-modality variation in the size and position of the delineated prostate on CT and MR, evaluation of CT-MRI image registration methods and investigation into the potential reduction in bladder and rectum dose from planning on the MRI delineated prostate.

**Materials and Methods**
Three patients with histologically proven cancer of the prostate underwent pre-treatment CT and MRI imaging. The prostate was delineated on each scan by four clinicians. The inter-observer variation for the whole prostate, prostatic base and apex was quantified using a variety of metrics. Three methods of image registration were tested to fuse the CT and MRI images, and evaluated to find the method that minimised the inter-modality variation at the base of the prostate. Treatment plans were prepared for each delineation of the prostate to quantify the possible dose reduction to the bladder and rectum through use of the MR prostate delineation.

**Results**
A significant difference in the prostate volume as delineated on CT or MRI was found (mean volume 30.9cm\textsuperscript{3} and 24.2cm\textsuperscript{3} respectively, p=0.0002). The mean reduction in volume from CT to MRI was 26%. The inter-observer variation was significantly smaller at the base of the prostate than the apex for both modalities. Auto-registration using a volume of interest around the base of the prostate minimised the inter-modality variation at the prostatic base, and this was used to fuse the CT and MRI images for treatment planning. Statistically significant volume reduction was achieved at all DVH points for the OARs (p<0.05) including clinically significant volume reductions for the rectum V30, V40, V50, V60 and V70.

**Conclusions**
The inter-observer variation was found to be significantly smaller at the prostatic base than the apex indicating that CT-MRI co-registration is most reliable at the base of the gland. Due to a smaller delineated prostate on T2 weight MRI, incorporating MRI imaging into the radiotherapy planning pathway by registering CT and MRI images leads to significant dose sparing to the rectum.

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**Commissioning and Testing the Performance of the PTW 1500 MR Array in the Magnetic Field of the MR Linac.**
Rukaiya Ali, Joe Berresford, James Agnew, Geoff Budgell
The Christie NHS Foundation Trust, Manchester, United Kingdom

The aim of this work was to commission the PTW 1500 MR Array and investigate its operation in a magnetic field to analyse the dosimetric consequences. The Elekta Unity MR Linac has a permanent 1.5T magnetic field running parallel to the bore which affects the response of detectors placed within the bore\textsuperscript{[1]} therefore verification devices require careful testing. These effects include the electron return effect; this creates a three dimensional change in dose deposited by secondary electrons due to the Lorenz force \textsuperscript{[2]}. The presence of air gaps within detectors can especially cause differences between doses measured with and without a magnetic field present \textsuperscript{[3]}.

The commissioning process included the acquisition of baseline measurements for the 1500MR array and patient specific treatment plan verifications.

Baseline measurements included linearity, reproducibility, dose rate and warm up tests. These were investigated in the presence of the magnetic field on the MR Linac and without the magnetic field on a conventional linear accelerator.

The linearity results in the presence of a magnetic field were within 1% of the standard 100MU exposure - comparable to the results on a conventional linear accelerator. Reproducibility of exposures delivered ten times was within ±0.1%, well within the ± 0.5% tolerance stated by the manufacturer. Results showed little
variation in the measured output with and without the magnetic field.

Dose rate measurements showed all central chamber readings to be within ± 0.2% of the mean; this agreed with the measurements without a magnetic field. Warm up measurements were acquired once per minute for 15 minutes after switching on the array and ± 0.2% variation was found. All results were comparable with and without the magnetic field present. Thus the array operates effectively in both situations.

A streamlined end to end system for verification of treatment plans using the array has been developed to test the effective transfer, planning and delivery accuracy of the Monaco treatment planning system and the MR Linac respectively. This included the production of an in-house QA platform to allow rapid, accurate and repeatable positioning of the array. The amount of build-up placed above and below the array was chosen to mirror current clinical practice. The build-up below the array allows sufficient backscatter and positions the array at the linac isocentre; this is required since the couch has no vertical motion within the bore. Orthogonal images acquired with the MV imaging panel are used to check the alignment of the array centre with the MR linac radiation isocentre; this is required since there is no laser positioning system. A variety of patient specific treatment plans have been delivered using the system for various sites including prostate, lung and head and neck plans. This system is now being used to commission the MR Linac for clinical use.


Wednesday 19th September, 13.30 – 15.00

**Paediatric Imaging**

**Optimisation in paediatric CT**

Mark Worrall, NHS Tayside

This talk presents the results from a Scotland wide paediatric CT optimisation exercise that involved sending a 1, 5 and 10 year old CIRS anthropomorphic phantom to CT scanners around Scotland and undertaking head and chest examinations at each site. The results were analysed and each participating site compared against the national distribution to identify the best and worst performing sites. Information about the acquisition technique from the best performing sites was shared with the poorer performing sites to allow them to explore them as potential routes towards optimisation.

The lessons learned from this exercise are likely to be relevant to sites throughout the UK and beyond. An overview of the lessons learned will be given, with a particular focus on the selection of examination kV, the use of manufacturer protocols vs. modified adult protocols and the particular pitfalls of setting up CT AECs for paediatric examinations.

**Lens doses from CT scans of the head in children**

Richard Harbron1,2, Mark Pearce1,2, Liz Ainsbury3, Sue Edyvean4, Choonsik Lee5

1Newcastle University, Newcastle-upon-Tyne, United Kingdom. 2NIHR Health protection research unit in chemical and radiation threats and hazards, Newcastle-upon-Tyne, United Kingdom. 3Public Health England centre for chemical and radiation threats and hazards, Chilton, Didcott, United Kingdom. 4Public Health England, medical dosimetry group, Chilton, Didcott, United Kingdom. 5Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, Bethesda, USA

Background: Recent epidemiological evidence has suggested the threshold dose to the lens required for cataract induction is lower, at around 500 mGy, than previously thought (2000 mGy). Currently, little information exists on the potential for cataract induction following CT scans of the head. Based on
previously published lens dose estimates of around 50 mGy, cataracts would appear to be an unlikely consequence of a single CT scan. However, some patients undergo multiple scans, especially in childhood, thus could potentially receive large cumulative lens doses.

Methods: The cumulative frequency of head scans among a cohort of 410,997 children and young adults who received a CT scan in the UK between 1985 and 2014 was calculated. For a sample of these scans (n=668), complete sets of images were obtained and the level of inclusion of the eyeball and lens recorded. Lens doses were estimated using NCICT [1] for a range of eye inclusion scenarios and different scanner outputs representing past and current practice.

Results: Of the 284,859 cohort members who underwent a head scan, 72% had a single recorded scan, 3.5% had ≥5 scans and ≈1% had ≥10 scans. The lens was included within the imaged region for 57% of reviewed scans overall, though practice varied considerably between hospitals. Some centres included the eyes for almost all scans. Depending on exposure factors, estimated lens doses were 2-7 mGy where the eye was fully excluded from the primary exposed region, and 20-75 mGy when fully included. Where helical scanning mode is used, z-overranging is likely to result in inclusion of the lens within the exposed region, even if excluded from the imaged region.

Conclusions: For the majority of children, doses will be well below the assumed threshold, suggesting the risk of cataract induction may be non-existent. A subset of children, who undergo sufficiently many head scans with the eyes included within the primary beam, may be at risk of cataract development, however. There are clinical advantages in visualising the eyes, therefore eye inclusion should not necessarily be regarded as a failure of radiation protection. Finally, our findings should be placed in the context of dosimetric and epidemiological uncertainties.

References:

Is the use of the anode-heel effect better than a gonad shield in paediatric radiography?
Anna Gardiner1,2, Julie Horrocks1,2
1Barts Health NHS Trust, London, United Kingdom. 2Great Ormond Street Hospital for Children NHS Foundation Trust, London, United Kingdom

There are differing opinions as to the effectiveness of the use of gonad shields in paediatric imaging. The aim of this work is to establish whether the use of gonad shields is effective and to evaluate the use of the anode-heel effect to reduce the gonad doses.

Current practice was assessed by reviewing a sample of 21 patients aged 5 to 18 who underwent pelvis examinations using gonad shields in a dedicated paediatric hospital. Of these examinations, only four gonad shields were positioned correctly: 3 males, 1 female, the majority of the remainder (10) being placed too high.

To evaluate the impact of the anode-heel effect, measurements were made on two clinical systems with different anode angles (13° and 19°) at a range of source to image distances (SID) and kVs. A Raysafe dosemeter was used to measure the dose profile along the anode-cathode axis at 2cm intervals at the table top.

The two systems exhibited different dose profiles. The dose reduction at an SID of 115 cm and 10 cm from the central axis was 14% and 9% for the 13° and 19° tubes respectively. Therefore, orientating the patient to make use of this phenomenon could be effective in reducing gonad doses.

Effective dose and the dose to the gonads will be estimated using PCXMC to compare the use of gonad shields to the use of the anode-heel effect. It is hoped that this will enhance clinical practice at this hospital, optimising the effective dose received by this patient population.

Technical evaluation of low-kV technique for the imaging of paediatric extremities
Ell-Noora Salo, Nick Weir
Royal Infirmary of Edinburgh, NHS Lothian, Edinburgh, United Kingdom
Introduction: Paediatric extremity imaging is challenging due to the relatively low subject contrast, with typical techniques utilising 50-60 kV. Low-kV methods using 40 kV without additional filtration have been proposed to increase the contrast-to-noise ratio (CNR) [1, 2]. However, the CNR measurement does not provide information on reproduction of fine detail, an important aspect of extremity examinations. We postulated that contrast-detail detectability (CDD) may provide a better overall assessment of image quality. However, no published studies could be found assessing the effect of low kV technique on CDD. Therefore, the aim of this study was to investigate the effect of low kV technique on CDD and to compare its sensitivity with measurements of CNR.

Methods: All images were acquired on a Philips DigitalDiagnost (Philips Healthcare, The Netherlands) x-ray unit. Entrance surface air kerma (ESAK) was measured for the default Wrist AP exposure for a two-year-old patient (Table 1), and the exposure factors for the 40 kV technique were selected based on this measurement to yield a range of ESAK values (Table 1). For all exposures, a 10 mm thick Perspex phantom was used to simulate the attenuation by the tissue [2].

For the measurement of CNR, a 1 mm thick aluminium square was placed on top of a uniform 10 mm Perspex phantom. Three images were acquired using settings in Table 1 and raw image processing. CNR was calculated from linearised pixel values.

For the assessment of CDD, a CDRAD phantom [3] was placed centrally on the detector. Five images were acquired with each of the acquisition settings in Table 1 using normal clinical processing. Images were analysed using CDRAD Analysis 2.1 software [3] and Inverse image quality figures (IQF inv) averaged for each image set.

Table 1. Summary of exposure factors and the resulting entrance surface air kerma (ESAK) values. All exposures were made at 100 cm FID.

<table>
<thead>
<tr>
<th>kV</th>
<th>mAs</th>
<th>Additional filtration</th>
<th>ESAK (µGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1</td>
<td>0.1 mm Cu + 1 mm Al</td>
<td>6.2</td>
</tr>
<tr>
<td>40</td>
<td>0.4</td>
<td>0</td>
<td>5.1</td>
</tr>
<tr>
<td>40</td>
<td>0.6</td>
<td>0</td>
<td>6.6</td>
</tr>
<tr>
<td>40</td>
<td>0.8</td>
<td>0</td>
<td>9.0</td>
</tr>
<tr>
<td>40</td>
<td>1.2</td>
<td>0</td>
<td>13.8</td>
</tr>
<tr>
<td>40</td>
<td>1.6</td>
<td>0</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Results and Discussion: The linearised CNR and the IQF inv for different exposure factors are presented in Figures 1 and 2, respectively. The linearised CNR is improved with the 40 kV technique: at similar ESAK, the CNR with 40 kV is 10 % better than with the reference technique. In contrast, the IQF inv displays a more complex relationship with the 40 kV technique. With similar ESAK, the IQF inv is 10 % lower than the reference technique. The same IQF inv is achieved using ESAK 44 % higher than the reference technique. The different behaviour of CNR and IQF inv could be a result of a possible loss of resolution at lower kV [1] or the effect of image processing in the CDRAD images.

Wednesday 19th September, 13.30 – 15.00
Clinical Engineering/Physiological Measurement

Advances in cardiac Holter monitoring lead to improved diagnosis and treatment of arrhythmias
Stephen O’Connor¹, Benedetta Sabiu²
¹City, University of London, London, United Kingdom. ²Bioengineering, Strathclyde University, Glasgow, United Kingdom

12 lead ECG and Holter monitoring, HM, remain the most common tools for examining the heart rhythm. Norman Holter’s ambulatory ECG recording¹ has been a mainstay of clinical practice to diagnose cardiac rhythm disorders since 1961, traditionally recording every heartbeat for 24 hours. HM requires multiple electrodes on the chest and a recording system, usually worn on a belt or on a holster strap. Even today, these systems remain bulky and difficult to conceal in public, Fig. 1.

Figure 1. Holter monitoring systems

The electrodes often disconnect, especially during sleep and cannot be worn during showering. Exercising can also result in electrode disconnection due to perspiration and activity. Multiple views of the cardiac signal and large inter-electrode spacing should allow P-wave detection, but unfortunately the data yield is poor.

Patch monitors, PM, have been developed recently in attempts to overcome shortcomings of the conventional HM systems. PMs allow for longer duration monitoring and, consequently, have matched or outperformed HM yields, Xio patch™ (iRhythm Technologies) vs. Holter², although the comparison, is merely one of compensating for lower diagnostic yield on a daily basis by increasing the duration of recording. These patch systems with their short vector(s) make the ECG’s P-wave signal detection relatively difficult, but they compensate partially by being easier to wear and adhering for longer.

However, the key to improving diagnostic yield is the quality of the P-wave, regardless of the specific duration of recording. P-wave clarity, its morphology and relationship and timing to the QRS is crucial for defining an arrhythmia’s specific mechanism. The Carnation™ Ambulatory Monitor³, Fig. 2, placed on the sternal mid-line, with a noise floor of 2μV is P-wave centric and is the first to outperform the conventional HM over the same 24-hour recording period, giving 46% actionable data cf. 12% from HM in 50 pts.

A recent paper⁴ compared CAM vs. Zio-XT in 29 pts who wore both monitors over the same time period. Primary outcomes compared with ECG signal clarity and whether there were differences in rhythm types diagnosed by the monitors. Secondary endpoints considered whether variance in findings caused differences in clinical decision making. Important findings were: 1. CAM identified more atrial tachycardias, atrial flutters and non-sustained ventricular tachycardias cf. Zio; 2. CAM ECGs ranked higher in clarity than Zio; 3. CAM and Zio were both easy to apply and remove as well as being comfortable to wear; 4. Differences in specific arrhythmias diagnosed by the two systems may result in different clinical decision making.

Actionable data can lead to initiation / modification of pharmaceutical agents, implantation of a pacemaker, defibrillator or cardiac resynchronisation therapy system, an ablation of the identified arrhythmia or any combination. Arrhythmia diagnosis must be correct to deliver the correct therapy.
Development of a cost-effective and flexible telemonitoring system for COPD patient supported discharge schemes
Prawin Samraj¹, Stuart Watson¹², Nawar Bakerly¹
¹Salford Royal NHS Foundation Trust, Salford, United Kingdom. ²University of Manchester, Manchester, United Kingdom

Background
The incidence of Chronic Obstructive Pulmonary Disorder (COPD) in the UK is approximately 1.2 million². The care of COPD patients therefore has a significant impact on resource and funding requirements for the NHS and healthcare internationally. To sustain, and improve, the quality of care for these patients will require the adoption of innovative assistive technology.

The COPD assessment and support unit in our hospital operate as an early supported discharge team and provide telehealth monitoring in which patients physiological and symptom data are collected and sent to the team to aid decisions on how that patient is managed on a day to day basis, providing a ‘virtual ward’. Currently, the unit hires telemonitoring kits which provide (i) physiological measurements devices, (ii) tablet devices for data collection and transmission of data and (iii) a back-end webserver/database for storage of patient data. Significant issues with the current service provision however are:

- Hire, maintenance and webserver hosting costs are a significant financial drain
- Unreliable / inconsistent physiological measurements due to manual data entry

Methods
To address the above issues, we have developed a complete telemonitoring system employing a modular approach using the Bluetooth Low Energy¹ (BLE GATT) and 4G wireless standards. This allows measurement devices to be easily swapped if they become obsolete and new devices added to support other clinical telemonitoring applications. Physiological data is directly transmitted to a tablet PC thereby eliminating human errors which could arise from manual entry. The system provides a compliance check and guides patients on taking consistent measurements. Two MySQL databases have been developed to store data collected from the telemonitoring device, one hosted within the Cloud and the other within the hospital firewall with all patient identifiable information stored in the second secure database. A clinician portal application has also been developed allowing provisioning of devices, messaging of patients, compliance checks, measurement threshold alerts and a graphical representation of trends.

Figure 1: Telemonitoring system incorporating wireless SpO2, NIBP and thermometer devices

Results
The system is currently undergoing trials with our COPD assessment and support unit. Early feedback is positive with the system considered to be easier to use, by volunteer subjects and staff, than the current system it is designed to replace. A wide range of BLE-based physiological measurement devices are commercially available, and the devices selected, Nonin 3230 finger pulse oximeter (Plymouth, Minnesota, USA), DL8740 Ear Thermometer (Philips Consumer Lifestyle B.V., Drachten, Netherlands) and Evolv NIBP monitor (Omron Healthcare LTD, Kyoto, Japan) have all been found to meet the quality and safety standards applied by our Medical Equipment Management Service.

Conclusion
The ultimate objective of this project is to provide the developed software on a free open source basis to other NHS organisations, as a ‘tool-kit’, allowing them to adapt the system to provide a cost-effective telemonitoring solution suited to their own needs. The regulatory issues related to this objective are currently being explored.

References
1. BLE GATT Specifications (https://www.bluetooth.com/specifications/gatt)

Evaluating the Robustness of Atrial Fibrillation Detection Algorithms in the Presence of Random Measurement Errors
Sarah Whitbourn¹,², James Blake², Frank McArdle², Andrew Sims²
¹South Tees Hospitals NHS Foundation Trust, Middlesbrough, United Kingdom. ²Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, United Kingdom

Introduction
Atrial Fibrillation (AF) is the most common sustained cardiac arrhythmia and leads to an increased stroke risk. Often AF is asymptomatic and/or paroxysmal so can be undiagnosed meaning potentially life-saving therapies can be delayed.

AF is characterised by an irregular heart rhythm. Non-invasive blood pressure (BP) monitors rely on pulse detection and have been shown to be effective for AF screening through analysis of pulse interval timings [1]. Ambulatory BP monitors (ABPMs) take multiple BP measurements over an extended time period so may provide additional screening opportunities.

As most AF algorithms are validated using RR intervals from ECG, we previously investigated the extent to which pulse intervals from an ABPM could be used to estimate RR intervals in healthy subjects and found that, in this population, RR intervals could be estimated with no systematic error and a random measurement error with standard deviation of approximately 10ms [2]. The aim of this study was to determine the impact of this random measurement error on the sensitivity and specificity of published AF detection algorithms using ECG data from open-access databases.
Methods

Eight AF algorithms that utilise pulse interval timings were identified. A training dataset consisting of one-minute ECG segments was used to determine optimal parameters for each algorithm.

A further two datasets were then used to validate these parameters and test the robustness of each algorithm in the presence of random measurement errors. The algorithms were applied to both datasets to estimate baseline values for sensitivity and specificity. Increasing amounts of simulated random measurement errors (up to 50ms standard deviation) were then added to the RR interval timings and the sensitivity and specificity recalculated to determine the potential impact of these errors.

Results

All eight algorithms demonstrated high sensitivity and specificity when applied to the test datasets, with values greater than 90% being achieved in many cases.

The majority of the algorithms were robust in the presence of increasing measurement errors, demonstrating high sensitivities and specificities even when up to 50ms of measurement error was introduced. In particular, when considering the measurement errors potentially introduced by ABPMs (approximately 10ms), most algorithms only showed small changes in sensitivity and specificity from their base levels (absolute difference less than 3%).

Conclusion

These results imply that there is potential to apply RR-interval based algorithms to pulse intervals obtained from ABPMs as a way of opportunistically detecting AF.

References


Design of a device for the delivery of a variable oxygen-nitrogen mix to achieve desired blood oxygen saturation levels to aid in the assessment of pulmonary function

Rachael H Andrews1, Barry Nesbitt1, Sonya Sireau1, Stefan J Marciniak2,1, Robert I Ross Russell1,2

1Cambridge University Hospitals NHS Foundation Trust, Cambridge, United Kingdom. 2University of Cambridge, Cambridge, United Kingdom

Background: D. Sapsford and G. Jones developed an algorithm to describe gas exchange in the lung, which allows the non-invasive assessment of pulmonary shunt and ventilation/perfusion ratio (V/Q ratio). The algorithm requires the measurement of blood oxygen saturation at three or four different levels of inspired oxygen concentration. For one or more of these measurements, the blood oxygen saturation must be below 90%; in many patients, this requires inhalation of a gas mix with O2<21%. The data are used to reconstruct a curve that approximates the dissociation curve, with inspired oxygen concentration as the independent variable and blood oxygen saturation as the dependent variable. This assessment is required for use in various research studies involving children >6 months, children with scoliosis, neonates, adults with chronic obstructive pulmonary disease (COPD) and adults with liver disease who have a shunt. It also has potential for use as a clinical diagnostic tool.

Method: The Clinical Engineering Innovation team collaborated with the Clinical Engineering Anaesthetic & Clinical Equipment (ACE) workshop to develop a system that would allow a clinician to set oxygen concentration in the range 15-85% for delivery to a patient through a face mask. The Healthcare Design Toolkit was used to iterate and improve the design, and members of clinical staff were involved in evaluating prototypes. Prospective Hazard Analysis methods were used at key points in the project to consider any unintended consequences of the proposed design. The design was then iterated as required. The principal risk was identified as the unintentional delivery of hypoxic mix to the patient. This was mitigated by modifying the design to deliver medical air in the event of a fault. Another significant risk was over-delivery of oxygen, which would pose a risk of hypercapnic respiratory failure in patients with COPD. Again, the design was modified to mitigate this risk.
Results: A bench top prototype has been created and tested to the satisfaction of both the clinical engineering team and the clinical staff. The engineering team is refining the design to create a useable prototype to ensure it is suitable for initial clinical use in a research setting.

Discussion & Conclusion: A prototype device has been developed in-house to enable clinicians to carry out research into the relationship between oxygen concentration in inspired air, blood oxygen saturation and pulmonary function. Once approved, the device will be used in an upcoming research study.

References:

Design and manufacture of a low-cost mounting device for AAC (augmentative and alternative communication) devices
Maighread Ireland¹, Jessica Chiu²
¹Clinical Engineering Innovation, Cambridge, United Kingdom. ²North East London Wheelchair Service, London, United Kingdom

Background
Communication is vital for a child’s development; it increases their independence and social participation. The uses of augmentative and alternative Communication (AAC) devices are long-standing solutions to support communication to those who cannot rely on their speech.

Off-the shelf tablets can be used as communication devices; however they require expensive software and mounting devices to facilitate use. A charitable institute in North Mexico had been donated 32 tablets, to be used as communication devices in therapy and classroom teaching sessions. However the institute was unable to purchase suitable mounting devices, resulting in the tablets being shelved.

This project involved the design, and manufacturer, of a suitable and sustainable, low-cost mounting device.

Methods
First stage of the project was to identify and document the requirements that the design must satisfy. A comprehensive requirements specification may increase quality of the product and reduce design time and costs ¹. Multiple sources were used to compile the requirements specification:

1. Expert knowledge from engineers, and speech and language therapists, based in the UK.
2. A formal questionnaire and interviews with clinical and teaching staff.
3. Manufacturing requirements and restrictions from workshop engineers and local suppliers/manufacturers.
4. Observational studies of classroom and therapy activities to understand the intended environment.
5. Case studies for potential users, to understand needs of the individual.

Feedback from these sources was reviewed and combined to develop the functional specification. The MoSCoW ² prioritising technique was used to prioritise requirements.

Concepts were created and several phases of prototypes developed. Re-designs were required as a result of verification activities, identification of errors in design, or risk management activities.

Results
The requirements specification stage ensured that the design met the needs of the different user groups; patients, clinicians, and teachers. Observational studies of the intended environment were vital to the design, and resulted in reduced features of the product to ensure ease of use. Communicating and building a relationship with the workshop engineers ensured the device could be manufactured low-cost, in-house,
and therefore sustainable.

Several prototypes were generated, and a final design was implemented into services with good feedback from users.

Discussion
The project developed and implemented a sustainable solution into an environment that varied greatly from our normal. This involved over-coming unique; language, cultural, and environmental obstacles. The collaborative, open nature of therapists, teachers and engineering staff ensured the progress of the project. The project is on-going; a review of the products is in progress, aiming to make the design an open-sourced solution to allow other centres to manufacture the product. The institute is also applying for funding to increase their production.

References

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**Wednesday 19th September, 13.30 – 15.00**

**Radiotherapy Quality Assurance**

**A Novel Approach to Daily Dynamic MLC QA Using a Sun Nuclear QA3 Device**

Joshua Kirby, Kimberley Quinn, Orla Hayman, Jim Daniel

James Cook University Hospital, Middlesbrough, United Kingdom

**Objectives:**
As the leading centre for delivery of VMAT treatment fractions in the United Kingdom it has been essential to develop robust dynamic MLC QC to complement this advancement. These treatments utilise dynamic multi-leaf collimator (MLC) sequences to deliver complex dose distributions to target volumes. Positioning and movement inaccuracies in the MLCs will result in a dose delivery different to that intended. The aim of this project was to develop a robust daily check of the accuracy of dynamic MLC movement and to develop a user friendly environment for analysis of the results for all staff groups.

**Materials and Methods:**
The QA3 device (Sun Nuclear) is designed for routine daily QA with static fields with an accompanying database and software for reviewing results. Running a dynamic test on the QA3 and looking at the results when the software expects a static delivery can lead to incorrect interpretation of results. Software has been developed that analyses the raw data measured by a QA3 device (Sun Nuclear) for a dynamic MLC sequence (varying field width swept across the device in the A-B direction) for a 6MV flattened beam with static gantry. An internal web interface allows easy review of the captured results. The web interface is hosted locally and can be accessed anywhere in the department by both radiographers (to carry out the daily QA) and medical physicists (to investigate failures). Development has been in C# and the .NET framework and uses read-only access to the Sun Nuclear SQL database.

**Results:**
The key analysis metrics are the ratios between the nine ionisation chambers located in the centre and around the edge of the device. It has been demonstrated that these ratios differ when known errors in leaf bank position are introduced to the standard sequence and allow the identification of the type of error (e.g. leaves miss-calibrated towards A/B, leaf gap larger/smaller than expected or if there are variations across the leaf bank). An example of the difference in ratio is shown in figure 1.
Figure 1: The ratio of the left to right chamber for ten repeats for the standard sequence and then the sequence with known errors in MLC position.

The software has correctly identified all cases during testing where the leaf gap is 1mm larger/smaller than expected; the leaves are shifted 2mm towards A/B and also when there is a difference in position between the top and bottom of the leaf bank.

Conclusions:

This development has been rolled out clinically and gives confidence on a daily basis in the delivery of dynamic MLC fields and allows the rapid identification of potentially significant errors. The interface is easy to use and has been designed with feedback from multiple staff groups on its functionality. It has been demonstrated that the QA3 is a robust device for both static and dynamic fields.

Experience of the IBA Dolphin detector for measurement based patient specific quality assurance
Robert Lally, Sheila Loughlin, Andrew Reilly
Western Health and Social Care Trust, Derry/Londonderry, United Kingdom

Machine time for patient-specific quality assurance (PS-QA) is a precious commodity in a busy radiotherapy department. Therefore the PS-QA chain must be streamline and accurate. At our centre, 3D dose measurements are made using the SNC ArcCheck detector. This array consists of 1386 diodes (0.019 mm3) arranged in a cylindrical phantom with a uniform spatial resolution of 1 cm and a sensitivity of 32 nC/Gy. Whilst the array has proven to be an effective and accurate PS-QA tool, operators have reported set-up times in the region of 15 minutes. To improve efficiency in the PS-QA chain our centre undertook an investigation to identify an alternative solution to the ArcCheck with equivalent or greater accuracy.

One solution available at our centre was the IBA Dolphin detector, which IBA market with a 1 minute set-up and readiness for QA measurement time. This 40 x 40 cm2 2D array consists of 1513 air vented ionisation chambers arranged with a spatial resolution of 5 mm across the central area of the array (15 x 15 cm2). The array is operated alongside the IBA COMPASS software solution. Operators can follow two workflow approaches. The first approach involves exporting the DICOM RT Plan, CT, RT Structures and RT Dose to the COMPASS software prior to measurement. When the measurement is acquired, operators will be provided with a QuickCheck result, calculated using the operators pre-set gamma criteria template for that treatment site. Alternatively, measurements are acquired before export. This workflow enables operators to acquire measurements with no notice but sacrifices the assurance provided by QuickCheck. For either workflow, analysis in COMPASS can be 2D or 3D based. 2D analysis is a comparison of the TPS (compass) predicted fluence vs. Dolphin (compass) predicted fluence whilst 3D analysis is a comparison of the TPS computed dose distribution vs. COMPASS computed dose distribution vs. Dolphin reconstructed dose distribution. For PS-QA, the array is currently only released for 6 MV and 6 FFF.
To assess the suitability of the Dolphin for PS-QA at our centre, a retrospective PS-QA study was carried out using (n=41), prostate (n=46) and lung (n=7) patients. The Dolphin detector was calibrated following IBA set-up instructions. Plans were delivered to the Dolphin detector using a Varian TrueBeam v2.7 linac and analysis was 3D based.

Results of this study were positive. Improvements in efficiency were observed as without calibration the set-up and readiness for QA measurement time was 3 minutes, compared to the 15 minutes observed for ArcCheck. Deliberately introduced errors, including incorrect plans, were identified by the Dolphin. Gamma analysis results at 3%/3mm and 2%/2mm for breast, prostate and lung were 100%, 94.8%, 99.7%, 97.9% 96.5% and 85.3% respectively. An action level, below which further investigation is performed, was set based on the 95% CI to result in 5% of plans requiring investigation. Action levels were set at 99.8%, 83.1%, 98.2%, 91.2%, 89.4% and 71.9% respectively.

Design and implementation of a phantom for quick and comprehensive quality control of 4DCT scanning for Radiotherapy planning
Pooja Gohil, Matthew Lowe, Philip Whitehurst
The Christie NHS Foundation Trust, Manchester, United Kingdom

An imaging phantom has been developed to enable quick and comprehensive testing of the integrity of 4DCT scanning. The phantom enables testing of 4D image reconstruction as well as Hounsfield unit consistency, image scaling and orientation.

The phantom, shown in Figure 1(a) and 1(b), comprises a static frame and a moving component that can undergo periodic motion simulating breathing over a range of clinically realistic breath rates with a 27mm amplitude. Within the stationary component of the phantom, markers with known spacing enable measurement of image scaling and inserts with materials covering a range of clinically relevant densities allow for Hounsfield units to be assessed (Figure 1(c)). The moving component consists of a cylindrical balsa wood insert (approximating lung density) containing 2 Perspex spheres representing tumours of different sizes. A zigzagged wire running along the length of the moving component enables testing of 4DCT reconstruction accuracy (Figure 1(d)).

The phantom has been designed for use with the Philips respiratory belt which can be attached to the moving platform using Velcro to provide a respiratory signal for the 4DCT scan. The motor can be battery operated for further ease of set up.

The imaging phantom has been commissioned for the rapid return of CT scanners into clinical use after servicing.

(a) A schematic diagram of the phantom. (b) Picture of the phantom.
Purpose: To present the clinical application of two novel methods of measuring the dosimetric leaf gap (DLG) of a multi-leaf collimator (MLC) for the purpose of machine specific quality control (QC) measurements.

Method: One and two dimension DLG distributions (1D DLG and 2D DLG) were derived using commercially available diode array detector system (Profiler™, Sun Nuclear Corporation) and an electronic portal imaging device (Varian-EPID). The 1D and 2D DLG methods of measuring DLG distributions were implemented as part of a routine machine specific quality control on Varian linear accelerators equipped with Millennium MLC. 1D and 2D DLG baselines and tolerances were derived and used to monitor MLC behavior.

Results: The 1D and 2D distributions show characteristic variations in profile across the MLC leaves due to interleaf transmission. Both methods demonstrate reproducibility and consistency over time, allowing evaluation from baseline values. 1D and 2D DLG distributions showed comparable sensitivity and provide relevant information about the gap of each MLC leaf pair. A tolerance of 0.2 mm on the 1D and 2D DLG average is used along with a qualitative visual evaluation of the distribution change from baseline. The 1D and 2D DLG distributions have been effectively used to detect changes in the MLC calibration during a MLC controller upgrade and were also used to detect a MLC leaf non-parallelism in a recently commissioned True Beam™ linear accelerator.

Conclusion: Two DLG methods, including their analysis software have been used to monitor the behavior of dynamically delivered MLC radiation fields. Both methods can be effectively used for machine specific MLC quality control.
Understanding Range Uncertainties in Proton Beam Therapy for Paranasal Cancer for the new UK service – a critical review of the evidence base
David Kirk¹, Mike Kirby²
¹Radiotherapy Department, The Christie NHS Foundation Trust, Manchester, United Kingdom. ²Directorate of Radiotherapy, University of Liverpool, Liverpool, United Kingdom

A second NHS-based Proton Beam Therapy (PBT) service is being introduced into the UK this year; a higher energy facility which will allow clinicians to treat with protons, a wider range of cancers than previously possible in the UK, thereby anticipating potentially better outcomes for certain patients. Among these will be patients with tumours of the paranasal sinus. However, increased conformity from PBT leaves the treatment vulnerable to considerable error as a result of uncertainties in beam range. This is an important training aspect in developing a PBT service. As an initial cohort of patients, paranasal sinus cases are potentially vulnerable to range uncertainties from several diverse sources; treatment success is dependent on staff understanding, identifying and minimising these uncertainties during preparation, planning and treatment. This narrative review was conducted to examine in a systematic way the evidence base for range uncertainties for these patients, for the primary purpose of education and training for staff in the new UK PBT service.

The PubMed database was used for key searches relating to range uncertainty in PBT and PBT for the paranasal sinus in April/May 2015 and monthly thereafter to ensure currency. Papers were filtered and appraised critically for relevance and robustness. From an initial result of over 220 papers, 97 were reviewed for range uncertainty and 7 specifically for paranasal cancer. A follow-up-up-to-date search has been conducted (Feb 2018) where 16 and 8 further papers were critiqued respectively.

Key results from the complete review which could be used for staff training and education included (e.g.):

1. Patients ideally undergo preparation/planning without a fluid filled sinus. If possible, adequate drainage should be provided surgically prior to planning and the status of the sinus monitored using volumetric imaging during treatment; re-planning as necessary if changes occur. Verification CT (sometimes weekly) may be required to assess dosimetric impact despite initial good results using CBCT for this purpose.

2. The impact of weight change is likely to be minor for properly optimised plan. Ideally the distal end of the Bragg peak should never be placed directly against any OAR if significant weight loss is anticipated.

3. Variations in RBE values across the Bragg Peak are of concern and need further research, both to confirm the extent of change, clinical effect and methods of compensation. The currently assigned value of 1.1 would appear an appropriate initial approximation – but studies reviewed employed a range of values from 1.07 to 1.18 for the mid-SOBP

4. The 3.5% margin of uncertainty appears an older concept, but still works well for many cases. Modern facilities should examine this margin for each anatomical site or case basis, when extraneous factors are anticipated. By creating a custom margin increase for outlier cases, the margins for more general cases can potentially be reduced improving conformity.

This review highlighted numerous factors that contribute to range uncertainty for these patients; most require more detailed research but yet still can serve as preliminary recommendations for the preparation, planning and treatment in a new PBT service.
**Background:** Several studies report the use of deformable image registration for dose verification to OAR’s, during radiotherapy\(^3\)\(^5\). Currently timing of dose and volume verification is arbitrary\(^1\). Re-planning patients can be extremely time consuming, increasing the workload of the Multi-Disciplinary Team\(^2\). We aim to determine an appropriate interval for dose verification, defining justification for adaptive planning, for patients with SCC of the oropharynx.

**Methods:** 5 patients’ weekly KV-CBCT scans (6 scans per patient), acquired post-treatment were reviewed retrospectively. Image registration performed between primary (pCT) and CBCT confirmed the online bony match, pCT structures were then duplicated to the rigid registration. Parotid gland (PG) volumes were amended on the CBCT, verified by the consultant. The rigid registration was imported to VelocityGRID\(^\text{TM}\). A b-spline deformation model and CBCT Corrected Deformable, a 3-pass deformable registration was applied. The pCT image volume was re-sampled, selecting the deformable registration, and creating a new primary volume, where the volume boundaries are the same as the primary volume, creating a synthetic (sCT). Where primary and secondary volumes overlap, the operation deformed the primary volume using the deformable registration. Outside this area the primary voxels were copied without deformation. The reshaped volume has the unit values of the primary volume. The sCT was then imported to Eclipse\(^\text{TM}\); a further image registration between CBCT and sCT performed, and the amended structure set applied to the sCT. The sCT verification plans were created, calculated and compared with the pCT plans, for the same number of treatment fractions.

**Results:** The 95% dose coverage to the planning target volume appears comparable between sCT and pCT calculated plans (Figure 1). Over the treatment course the ipsilateral and contralateral PG mean dose increased at week 5 (3.6%, SD4.7 and 9.7%, SD7.4). The mean volume of the ipsilateral and contralateral PG decreased over the treatment course (-11.1%, SD15.5 and -16.3%, SD12.0) respectively at week 5.

**Conclusion:** Caution is required, as velocity is unable to calculate units for volumes outside the overlap area during the deformation. Assessment of patient volumes prior to CBCT acquisition, can ensure critical structures are within the scan limits. This will improve DVH accuracy. Further investigation is required on the accuracy of the soft tissue distortion within the deformed plans. We will continue using VelocityGRID\(^\text{TM}\) for this group, evaluating all OARs, to determine the need for adapting treatment at a relevant point within the course.

**References:**

1. Brown, E et al. (2016). Head & neck adaptive radiotherapy: Predicting the time to replan.

**Figure 1:**
Impact of Genomics on the Future of Medical Physics and Clinical Engineering Services - Improving Patient Outcomes

A Douglas MBE
NW Coast Genomic Medicine Service, Liverpool Women’s Hospital, Liverpool, UK

This talk will focus on the impact of the 100,000 Genome Project and how this project is having a transformational impact on the way we care for patients in the NHS. I will present the evidence on how this project is creating a paradigm shift in improving cancer patient outcomes, moving from a ‘once size fits all’ to a more ‘personalised and targeted therapy’. In this talk, I will introduce a not so new ‘omic’ topic – radiogenomics. This is a new direction in cancer research that has emerged in recent years, which focuses on the relationship between imaging, phenotypes and genomics. This new direction is referred to as radiogenomics, radiomics or imaging genomics. I will introduce the topic of radiogenomics and discuss the radiogenomic approach and how radiogenomics offers a practical way to leverage limited and incomplete data to generate knowledge that might lead to improved decision making, and as a result, improved patient outcomes. One example of this is the use of molecular imaging methods to study metabolomics, measuring the omics data with imaging in clinical oncology for treatment planning, using the application of dose calculation, lesion location, and delineation. The combination of omics information and the image-derived lesion information has a high potential to further enhance the treatment efficacy for oncological applications. I will present how Radiogenomics will play a significant practical role in cancer care and impact on the future delivery of Medical Physics and Clinical Engineering in the NHS.

Engineering the future of clinical engineering quality assurance

Timothy Foran, Mark Devine, John O'Meara, Geraldine O'Reilly
St. James's Hospital, Dublin, Ireland

Despite the proliferation of paperless technologies, the practice of clinical engineering in hospitals is still heavily paper based. Clinical engineering departments utilise a broad variety of test and measurement devices with varying levels of user interface and interoperability. Often it can be difficult to extract results and test reports from test equipment in a digital format. Paper copies of results are transcribed into asset databases which is time consuming and prone to transcription error. This paper describes the design and engineering of a prototype device that incorporates wireless technologies to streamline the test and measurement function; conceptual ideas are explored and assessed in the context of the typical clinical engineering role.

The prototype device explores the use of RFID identifiers and wireless cloud based data solutions as a means of rapidly and efficiently carrying out routine QA tasks. The device incorporates a number of modules that are microprocessor controlled to manage rapid RFID identification of devices, carry out the test function and wirelessly send the resulting data to a cloud based service. The emergence of friendly modular microprocessor systems (Arduino) and accessible cloud based IoT software (e.g. ThingSpeak™) facilitates rapid hardware development and feasibility studies to be conducted within the scope of clinical engineering research.

A test case is presented showing the efficiencies that may be made in screening ward based oxygen flowmeters for accuracy. Hospitals typically maintain large numbers of flowmeters across an expansive terrain, and it can be challenging to routinely assess their accuracy. Often removal of flowmeters from wards for testing in a lab environment is not practical and an efficient portable test system provides for a viable QA program to be enabled. The results from an audit of flowmeters using the prototype device are presented.

Medical devices typically found in the hospital environment are now generally well designed and show a high degree of reliability and stability. Nonetheless QA and routine checking is still an important part of the
clinical engineering function. This study concludes that the incorporation of wireless IoT technologies into the systems thinking of clinical engineering departments improves efficiencies and data integrity.

### Future of Clinical Engineering

Richard Scott, Sheffield Teaching Hospitals NHS Foundation Trust

As the NHS celebrates its 70th Anniversary it faces considerable challenges, which are articulated by NHS England, [1], as gaps in

- health and wellbeing
- care and quality
- funding and efficiency

The NHS England Five Year Forward view, [1] goes on to outline a blueprint for the future of healthcare. The UK Government has also developed a strategic vision for the Life Sciences, [2]. In parallel the Royal Academy of Engineering, [3] have recognized that a systems thinking approach is required to provide meaningful change to the healthcare landscape. Society has changed considerably in the 70 years since the NHS’s inception and so too has the role of the professional, [4].

The presentation will initially summarise and synthesize these developments, contextualizing the impact on and opportunities to Clinical Engineering services.

Clinical Engineering services have continually evolved to apply engineering solutions for patient benefit across a range of specialisms, ensuring healthcare technologies are effectively managed. Systems have been proposed to codify the approach to healthcare technology management [5] but there is an increasing need for the clinical engineering professional to reflect on how their practice and service delivery models adapt to meet the challenges the NHS faces.

A vision will be presented identifying possible new roles and service delivery models that lead to convergence of routine and innovation activities with the aim of maximising the engineers impact in supporting and advancing care.

### References

Development of a Multifrequency Doppler Spectral Analysis (MFDSA) algorithm for the assessment of arterial disease using ultrafast ultrasound imaging

Andrew Malone¹, Jacinta Browne¹, Sean Cournane², Andrew Fagan³
¹Dublin Institute of Technology, Dublin, Ireland. ²St. Vincent's University Hospital, Dublin, Ireland. ³Mayo Clinic, Rochester MN, USA

The use of Multifrequency Doppler spectral analysis (MFDSA) combined with ultrafast ultrasound acquisition times was investigated for the purposes of wall shear stress measurements in arteries. The development of arterial disease is of clinical interest as it is associated with increased risk of a number of life threatening conditions including heart failure, hypertension, diabetes mellitus, and cerebrovascular disease. Currently, diagnostic methods for arterial disease such as digital subtraction angiography and pulsed wave Doppler ultrasound rely on detection of flow disturbances caused by arterial stenoses. As the development of arterial stenoses is commonly a symptom of advanced arterial disease, the current diagnostic methods have limited usefulness as screening techniques. Wall shear stress, contrastingly, can be used to detect arterial wall stiffening, a symptom commonly seen at the onset of arterial disease. Consequently, evaluation of wall shear stress presents promising potential for use as a screening technique for arterial disease.

A key requirement in the assessment of wall shear stress is the accurate mapping of blood velocity close to the arterial wall. Therefore, it is of paramount importance that any technique measuring wall shear stress has a high signal-to-noise ratio (SNR) as well as good velocity resolution. MFDSA examines the inherent additional frequencies present in a finite ultrasound pulse offering improved signal to noise ratio (SNR) and, thus, providing a considerable advantage over conventional Pulsed-wave Doppler methods. Furthermore, combining MFDSA with ultrafast acquisition times has the potential to improve both the SNR and velocity resolution for the quantification of blood velocity.

A MFDSA algorithm was designed in MATLAB (MathWorks) to allow full 2-D spectral Doppler analysis of velocity. The algorithm was tested using a string phantom for a range of velocities (10 – 50 cm s⁻¹). The algorithm was also tested using a range of anatomically realistic arterial flow phantoms specifically constructed to exhibit varying wall stiffness values corresponding to different stages of arterial disease. The Doppler data was acquiring using an Aixplorer (Supersonic Imagine) ultrasound scanner in the ultrafast research mode. In Phase and Quadrature (IQ) data were acquired. The datasets were windowed and
filtered in the time domain before undergoing a 2-D discrete Fourier transform. The resulting 2-D frequency data were integrated with respect to the transmission bandwidth to produce a power spectral density function.

Preliminary results showed an average decrease in spectral full width half maximum of 13% and an average increase in SNR of 38% for the 2-D analysis with respect to traditional 1-D Fourier analysis. MFDSA combined with ultrafast imaging led to a marked improvement in the quality of blood velocity data which will ultimately improve the assessment of WSS. This technique, therefore, offers very good potential as a screening technique for arterial disease, allowing for earlier and safer medical interventions.

The dosimetric characterisation of an in-house method for Fricke gel dosimetry applied to the verification of stereotactic VMAT plans
Jackie Poxon, Marc Miquel, Niall MacDougall
Barts Health NHS Trust, London, United Kingdom

Background
Ideally a high resolution, 3D detector would be available for the measurement of complex radiotherapy techniques such as stereotactic radiotherapy and VMAT. Currently, 2D methods or low resolution detector arrays are predominantly used.

3D chemical dosimetry, for example polymer and Fricke gel dosimetry, has the potential to provide this high resolution measurement of the entire 3D dose distribution. Scanning with MRI allows the selection of any plane in any orientation for analysis, or the 3D quantification of the entire irradiated volume. Despite research efforts, 3D gel dosimetry is not widely used as a routine dosimetry tool in clinical radiotherapy.

A linac-based stereotactic radiotherapy is currently being commissioned at our centre. The aim of this project was to investigate a simple Fricke gel dosimetry technique for the verification of VMAT plans.

Methods
A streamlined method was developed for the manufacture of Fricke gelatine detectors in a basic laboratory within a clinical radiotherapy department. The $T_2$ quantification of irradiated detectors was carried out using an NMR spectrometer and MRI scanner. Dose response was characterised to convert $T_2$ to dose. Detector characterisation measurements were then carried out including dose response, inter-sample variation, chemical stability, dose rate and energy dependence using test tube detector samples measured using the NMR spectrometer. Larger volume samples were irradiated in a custom phantom and readout using the MRI scanner in order to evaluate detector uniformity, volume dependence and spatial stability post irradiation. Only once this full detector characterisation was complete, the optimised detector system was applied to conformal and complex VMAT stereotactic plans. Distributions were compared with the treatment planning system (Varian Eclipse v13) in terms of profiles and gamma analysis.

Results
The detector characterisation measurements demonstrated many benefits of this Fricke gel detector. The detector response was independent of radiation energy and dose rate. Larger volume detectors responded uniformly to homogeneous dose distributions. Detector response was stable over time if detectors were stored in the dark. Inter-sample variations were small, the dose response was linear to doses of greater than 20Gy and independent of detector volume. Therefore, calibration is simple, requiring only two small additional samples to characterise the detector response.

Post-irradiation blurring due to ferric ion diffusion occurred [figure 1] and was quantified for a range of dose gradients. However, as long as detectors were scanned within 1.5 hours of irradiation, spatial errors introduced due to diffusion were within 1mm.

Comparisons between measured and TPS dose distributions for a conformal plan and two stereotactic VMAT plans demonstrated good agreement, with only a small re-normalisation required [example in Figure 2].

Conclusion
A simple Fricke gel dosimetry technique has been implemented within our department for the measurement of stereotactic VMAT plans. Fricke gel dosimetry will be a useful addition to our range of dosimetric tools.
available for the commissioning and ongoing quality control of complex VMAT stereotactic radiotherapy.

**Figure 1.**

![Graph of Dose vs Distance](image)

**Figure 2.**

![Measured Horizontal profile](image)

![Gamma map (2%, 2mm)](image)

![TPS](image)

**Directional dependence correction factors for PSQA in SRS using the PTW microDiamond**

Thomas Loh¹, Louise Belshaw², Candice McCallum², Glenn Whitten², Denise Irvine², Alan Hounsell², Mark Grattan², Conor McGarry²

¹Technische Hochschule Mittelhessen, Gießen, Germany. ²Northern Ireland Cancer Centre, Belfast, United Kingdom

**Background**

Directional dependence is a potential issue when using a microDiamond (µD) detector for patient specific quality assurance (PSQA). Therefore, we characterised this effect using a novel phantom to determine correction factors for directional dependence (c_{dd}) and retrospectively applied these to PSQA.
Methods

22 SRS plans were recalculated in iPlan by resetting the planned couch rotation to zero. The difference between the calculated and measured doses for deliveries at couch zero and non-zero were analysed to characterise any directional dependence for dynamic conformal arcs. To obtain a matrix of $c_{dd}$ for arcs delivered at non-zero couch position a µD was placed in an in-house spherical PMMA phantom and irradiated from 450 different couch/gantry combinations (repeated 6 times) using TrueBeam Developer Mode (Varian). At couch rotation zero a full arc was delivered and all measurement data were normalized to that plane.

Results

Figure 1 shows the matrix of the obtained $c_{dd}$. Corrections up to 1.5% were found. Figure 2 demonstrates that applying $c_{dd}$ to PSQA with planned positions accounts for a significant proportion of the differences observed between coplanar/non-coplanar QA using a µD.

Conclusion

The measurement and application of directional dependent correction factors for a µD detector reduced the difference between measured and calculated dose for PSQA of SRS plans. Therefore PSQA should be performed with the detector in the identical orientation to that used when acquiring the directional dependence map.

Wednesday 19th September, 15.30 – 17.00

Automated Planning & RT Planning Comparisons

Automated multi-criterial plan optimization – potential, challenges and future
Ben Heijmen
Erasmus MC, University Medical Center Rotterdam, Department of Radiation Oncology

This lecture will start with an introduction in the Erasmus-iCycle optimizer for automated a priori multi-criterial optimization (aprioriMCO). The system generates for each patient a single Pareto-optimal plan that is also clinically favourable. This is fundamentally different from a posteriori MCO which features automatic generation of a Pareto frontier, after which the user has to select a clinically favourable plan, using so-called Pareto navigation. Comparisons with manual planning for several tumor sites will be used to demonstrate the high quality of the automatically generated plans. Automated planning with Erasmus-iCycle is highly suited for performing high quality planning studies that investigate differences between treatment techniques (e.g. coplanar vs. non-coplanar or protons vs. photons). The principles of this powerful feature and examples of planning studies will be discussed. The lecture will conclude with a discussion on challenges and future of automated planning.
Building and validation of RapidPlan models for use in PIVOTALBOOST clinical trial  
Nikki Laverick, Steven Livingston, Letitia Aitken, Andrew Aitken, Suzanne Currie  
Beatson West of Scotland Cancer Centre, Glasgow, United Kingdom

RapidPlan™ is a knowledge based planning tool which draws upon a library of treatment plans in order to estimate attainable dose-volume histograms and generate planning objectives for a given patient geometry. RapidPlan models for a variety of treatment sites have been previously reported and can result in lowered organ at risk doses compared to standardly optimised plans (1).

Multi-criteria optimisation (MCO) is a planning tool which creates multiple treating plans for each planning objective; the aim is to enable the planner to explore the Pareto surface to find the optimum clinical planning solution.

In this work, several RapidPlan models were built with the primary objective of creating and validating a RapidPlan model to be used in treatment planning for the PIVOTALBOOST clinical trial. Secondary objectives were to assess if using MCO in the creation of the model or reducing the number of plans used in model training impacted plan quality.

A total of forty patients who had received radiotherapy to the prostate and pelvic nodes were replanned according to the PIVOTALBOOST (Arm B) trial constraints, with a prescription of 60Gy in 20 fractions to the prostate and 47Gy in 20 fractions to the seminal vesicles and pelvic nodes. A second set of treatment plans were also produced for these patients using MCO.

Four RapidPlan models were created from this library of treatment plans; two using the standard treatment planning techniques and containing either forty or twenty plans in the models (Std_40 and Std_20 respectively) and two from MCO plans containing forty or twenty plans (MCO_40 and MCO_20).

All models were validated using ten test patients and compared with one another and with manually optimised plans in terms of target coverage and doses to organs at risk (OARs), in particular to rectum, bladder and bowel.

Coverage of the target volumes was comparable between all models and the manually optimised plans. All of the RapidPlan models achieved on average a reduction in OAR doses in comparison to the manually optimised plans.

The models built using MCO plans were able to achieve a greater reduction in OAR doses on average compared with the standard models, one example being a reduction in the mean rectal dose from the manually optimised plan of 2.4±1.1Gy using MCO_40 and 3.0±0.9Gy with MCO_20 compared with 1.6±0.8Gy using Std_40 and 1.7±0.8Gy using Std_20.

Reducing the number of plans used to build the models has not significantly impacted the model quality and indeed the MCO_20 model often achieves the lowest rectal and bladder doses.

RapidPlan models have been built which are suitable for use in planning for the PIVOTALBOOST clinical trial. Using MCO to optimise the training plans for the models achieves lower OAR doses whilst maintaining PTV coverage, resulting in higher plan quality. A high quality model can be achieved using only the minimum number of training plans.

References  
(1) Fogliata, A. et al. RapidPlan head and neck model: the objectives and possible clinical benefit, Radiation Oncology 12:73, 2017

Improved organ at risk dose prediction model for head and neck VMAT  
Tom Marchant, Matthew Ward, Philip Whitehurst  
The Christie NHS Foundation Trust, Manchester, United Kingdom

Introduction  
Head and Neck (H&N) radiotherapy plans show a large degree of variability in shape and position of the target volume in relation to nearby organs at risk (OAR). This means it is difficult to set generic plan
optimisation objectives for OAR dose which are suitable for all plans. Instead it is common to iteratively refine OAR dose objectives during planning to achieve an optimal solution for each case. This process involves multiple, time-consuming plan optimisation steps. In this work we develop a predictive model of achievable OAR dose based on a library of existing H&N VMAT plans. This allows individualised OAR dose objectives to be set for each patient, thus saving time by reducing the number of optimisations required during planning.

Methods

A new 2-dimensional model to predict OAR dose was developed, providing improved prediction accuracy compared to prior work using 1-D models [1, 2]. Data from 160 recent H&N VMAT plans was used to build the model. For each patient a series of expansions of the PTV were created (2-20mm in 2mm steps), and the overlap of each expansion with each of four OARs was calculated (right and left parotid, larynx and oral cavity). The overlap volume was plotted as a function of PTV expansion, and a straight line fitted to the data. This yields measures of the OAR proximity to PTV (x-axis intercept of the line, X) and of OAR orientation relative to the PTV (gradient of the line, M). Higher gradient indicates that overlap increases more quickly with PTV expansion. The OAR dose achieved in the clinical plan was plotted in 3D against X and M. Finally a 2nd-order polynomial surface was fitted to the OAR dose vs. X and M data, to form the prediction model. Separate models were generated for parotids and oral cavity/larynx. Success of the model was tested by generating new plans for seven patients using the OAR dose objectives predicted by the model. Plan quality after a single optimisation was compared to the accepted clinical plan, in terms of PTV coverage and dose to OARs.

Results

The model was able to predict clinical plan OAR doses with a mean error of less than 40cGy and standard deviation of 309cGy (parotids)/432cGy (oral cavity/larynx).

![Figure 1: (a) Model fit to parotid dose vs proximity and orientation metrics (b) Predicted vs actual parotid dose for 160 plans.](image)

New plans generated with a single optimisation had PTV coverage and OAR doses generally similar to (within 4%) or better than the original clinical plan, except for one case where the OAR was far from the PTV and received a very low dose.

Conclusion

An improved predictive model of OAR doses for H&N VMAT planning has been developed. It is anticipated that the model can be applied to save time during planning by reducing the number of optimisation steps required.

References

Auto-contouring for breast patients with Mirada
Robert Chuter\textsuperscript{1,2}, Carmel Anandadas\textsuperscript{1}, Philip Whitehurst\textsuperscript{1}
\textsuperscript{1}The Christie NHS Foundation Trust, Manchester, United Kingdom. \textsuperscript{2}The University of Manchester, Manchester, United Kingdom

**Purpose** – Breast plans make up a large fraction of patients treated at most centres. Delineation of the heart and lungs for breast patients therefore takes a large proportion of clinician’s time, and to reduce this burden auto-contouring is being utilised more frequently. This work investigates using Mirada for CT delineation of breast patients.

**Methods** – Using a leave one out method we used Mirada RTx v1.6 (Mirada Medical, Oxford) to auto-contour 10 breast patients with the clinician approved contours as input. The auto-contours were compared to the clinician contours using DICE and Distance to Agreement (DTA). A comparison of the mean dose to the heart using both the clinician drawn contours and the Mirada contours was also performed. The time it took the clinician to edit the auto-contour and re-draw the heart was also measured.

**Results** – An overall comparison of the Mirada auto-contours to the clinician drawn contours for the heart and lung is shown in Figure 1. The time it took the clinician to edit the auto-contour and re-draw the heart contour is shown in Figure 2 (left). Additionally the mean heart dose for clinician drawn contours and the auto-contours is shown in Figure 2 (right).

**Conclusion** – The average DTA and DICE illustrates that the lung contour is similar to the clinical contours. The heart contour shows larger differences to the clinical contours. However, the difference in mean dose to the heart reported from the clinical and auto-contours show good agreement. The value of using auto-contouring even if it is not initially acceptable is that it takes half the time to edit the auto-contours as it does to draw them. Further efficiency savings were obtained by using Mirada’s WorkFlow Box as this server based system involves no patient by patient input.
Thursday 20th September 2018

Thursday 20th September, 09.00 – 09.30
Collaboration with Industry

Collaboration with Industry
Sybo Dijkstra, Philips

Awaiting abstract

Thursday 20th September, 09.30 – 10.30
The Future of Health Technology Assessment in Physics and Engineering in Medicine I

Introduction to us, HSST, and how the session came about
Emmanuel Akinluyi, Guy’s & St Thomas’ NHS Foundation Trust & Alys Gilbert, Sherwood Forest Hospitals NHS Foundation Trust

This is an introduction to the session on The Future of Health Technology Assessment in Physics and Engineering in Medicine. We will introduce ourselves, the HSST programme and how the session has come about.

Health Technology Assessment and clinical engineering trends, gaps and opportunities: IFMBE and WHO prospective
Leandro Pecchia, University of Warwick

The Official Journal of the European Union stated in September 2015 that “modern medicine predominantly secures important advances through the use of the products of biomedical engineering” (2015/C 291/07). In fact, medicine has been constantly reshaped by medical devices, which are the main outcome of biomedical engineering (BME). The number of medical devices that are going to be introduced in the market is growing very fast and data on new patent applications per year suggest that this number will soon overcome the one of new drugs. Clinical Engineering is the branch of biomedical engineering which takes care of medical devices in hospitals. Therefore, modern clinical engineering is called to constantly update its focus and contribute to all the medical device lifecycle, including their assessment, although Health Technology Assessment (HTA) is not a traditional topic for clinical engineers training.

How is the international community of BMEs facing this new challenge? What will be in future the role of clinical engineers in HTA? How is this affecting the body-of-knowledge of clinical engineering?

This talk will recall fundamental concepts and criticisms of Health Technology Assessment (HTA) of medical devices, and will present the activities of the International Federation of Medical and Biological Engineering (IFMBE) Health Technology Assessment Division (HTAD, http://htad.ifmbe.org/), in cooperation with the WHO unit for Medical Device, aiming to support clinical engineering participation to studies of HTA for medical devices. This will cover the IFMBE HTAD summer school program, the freely available IFMBE HTAD eLearning platform (http://www.htad-ifmbe-elearning.org/) and the recent publication on recommendations for guidelines of HTA.
King’s Technology Evaluation Centre (KiTEC) and device HTA: building on the past, looking to the future
Keevil SF
Medical Physics Department, Guy’s and St Thomas’ NHS Foundation Trust, UK and KiTEC, School of Biomedical Engineering and Imaging Sciences, King’s College London, UK.

Medical device assessment has a long track record in the NHS. In the 1970s, a number of assessment centres were established by the then Scientific and Technical Branch (STB) of the Department of Health and Social Security (DHSS). These included the King’s Centre for Assessment of Radiological Equipment (KCARE), opened in 1977 at King’s College Hospital. KCARE supported centralised purchasing by the DHSS by performing extensive physical measurements and patient examinations on x-ray equipment installed temporarily in a dedicated facility in the hospital. Similar centres were established focusing on digital radiology (FAXIL), CT (ImPACT), gamma cameras (GCAT), ultrasound (UEEP) and MRI (MagNET), as well as a host of technologies outside the imaging arena. In the period 1977-1995, KCARE assessed around 100 devices; 60% were found to be unsatisfactory in some way and 11% were removed from the UK market. With establishment of the NHS Breast Screening Programme in 1988, KCARE became responsible for testing mammography equipment prior to purchase for the programme.

NHS reforms in the 1990s, particularly the formation of NHS trusts and the end of centralised purchasing, brought changes to the role and management of the centres. In 2005, responsibility transferred from the Medicines and Healthcare Products Regulatory Agency (MHRA), in this context the successor body to the STB, to the new Centre for Evidence-based Purchasing (CEP) within the NHS Purchase and Supply Agency (PASA). Over time many centres were closed, and the workload of the remainder shifted towards market surveys, comparative reports, equipment specification tools and health economic evaluation in place of hands-on technical assessment.

In 2010, the National Institute for Clinical Excellence (NICE) took control of the service, and put it out to tender. The aim was to commission four External Assessment Centres (EACs) for medical devices, one specialising in imaging. It was clear that NICE expected bidders to demonstrate both clinical and academic strengths, and so a bid was submitted that combined the experience of KCARE with the clinical expertise of the medical physics departments of Guy’s and St Thomas’ and King’s College Hospital NHS Foundation Trusts and academic strengths in imaging, health economics and medical statistics within King’s College London (KCL). The bid was successful, and the King’s Technology Evaluation Centre (KiTEC) was born.

KiTEC’s contract with NICE was renewed after another tendering exercise in 2014. We are currently negotiating a further new contract following successful tendering earlier this year.

The work of KiTEC is very different from that of KCARE in the early days. Assessment takes the form of analysing clinical and economic evidence, not testing of equipment. This can involve critiquing evidence submitted by a manufacturer, performing systematic reviews and meta-analyses of our own, and developing complex economic models. We also develop and seek funding for research proposals to address gaps in evidence identified by NICE advisory committees. As well as work on individual devices, we provide NICE with advice on specific types and applications of technology (e.g. cardiac CT scanning and amyloid tracers in PET).

KiTEC has developed into a generic health technology assessment (HTA) centre, and projects have included surgical devices, point of care tests and healthcare apps as well as imaging devices and software. A large part of our work now is to provide data management and analysis support for the NHS England Commissioning Through Evaluation (CiE) programme. Our staff are no longer mainly from a medical physics background, and include individuals with backgrounds in medicine, biomedical engineering, information science, medical statistics and health economics. Increasingly, we are applying our rare expertise in device HTA to support equipment manufacturers and other organisations as well as our work for NICE.
The first UK survey of doses from radiotherapy treatment planning CT scans for adult patients
Tim Wood¹, Anne Davis², Matthew Williams³, Rosy Plaistow⁴, Rebecca Lindsay⁵, James Earley⁶, Antony Palmer², Andrew Nisbet⁷
¹Hull an East Yorkshire Hospitals, Hull, United Kingdom. ²Portsmouth Hospitals NHS Trust, Portsmouth, United Kingdom. ³Velindre NHS Trust, Cardiff, United Kingdom. ⁴Cambridge University Hospitals NHS Foundation Trust, Cambridge, United Kingdom. ⁵St James Institute of Oncology, Leeds, United Kingdom. ⁶Royal Surrey County Hospital NHS Foundation Trust, Guildford, United Kingdom. ⁷Royal Surrey County Hospital NHS Foundation Trust, Guildford, United Kingdom.

Background - The first UK wide dose survey for radiotherapy CT planning scans has been completed. The survey was initiated by a working party of the Institute for Physics and Engineering in Medicine (IPEM).

Method – Patient dose metrics were collected for prostate, gynaecological, breast, 3D-lung, 4D-lung, brain and head/neck scans. Median values per scanner and examination type were calculated. National dose reference levels of CT dose index (CTDIVOl) and dose-length-product (DLP) values for each examination type are proposed based on the third quartile values from the whole data set.

Results – 68 radiotherapy CT scanners were included. Patient numbers per scan type ranged from 664 to 1527 across the seven examinations: The proposed reference levels for CTDIVOl (mGy) and DLP (mGy.cm) respectively are prostate 16 and 570, gynaecological 16 and 610, breast 10 and 390, 3D-lung 14 and 550, 4D-lung 63 and 1750, brain 50 and 1500 and head/neck 49 and 2150.

Head/neck and 4D-lung had the largest differences (18 times) in dose between lowest and highest dose scanners.

Problems with the data collected included some older scanners indicating maximum CTDIVOl not scan average; the lack of standardisation as to whether CTDIVOl is indicated for a 16 cm or 32 cm phantom for head scans; the lack of patient weight information available in many centres.

Conclusion – Evidence of clustering of results by scanner type suggests there is scope for protocol adjustment in some centres. Dose reference levels have been recommended to aid this.

Over-scanning in KUB CT: Potential for simple dose optimisation?
Cameron Anderson, Isabel Dodson, Bruce Walmsley
St George’s University Hospitals NHS Foundation Trust Trust, London, United Kingdom

Introduction:
Kidney, ureter and bladder (KUB) computed tomography (CT) scans are one of the principal examinations of a radiology department. Observation of coronal images of certain studies at our centre indicated imaging far superior to the kidneys. An assessment of the over-scan in KUB exams and an associated patient radiation dose was hence undertaken as described in previous studies [1-3].

Methods:
The KUB scans from one month (n = 113) were assessed, with images analysed to determine the number of axial slices superior to the kidneys. An associated “percentage over-scan” could then be determined. The vertebra at which a scan commenced was also assessed, alongside the vertebra at which the kidneys were fully encompassed. Images were determined to be over-scans if the percentage over-scan was greater than 10% [2] and/or the additional vertebrae included above the kidneys was greater than 1.

The effective patient dose associated with the unnecessary over-scan was calculated using two methods: firstly the average “unnecessary DLP” of scans was determined, and multiplied by the effective dose (ED) conversion factor published by Shrimpton et al. [4]. An assessment of additional dose was also completed using the ImPACT CT dose calculator by modelling the effect of adding the average over-scan distance.

Results:
Using the criteria of an over-scan distance of 10%, 48% of KUB scans were determined as such. Using the vertebra criteria, 41% of scans were deemed to be over-scans. The average over-scan was 10%, with a maximum of 25%. With regards to axial distance, the average over-scan was 4.7cm with a maximum of 13.8cm. Vertebra analysis indicated scans were commenced as high as T6, whereas the maximum kidney location was at T10.

The average unnecessary DLP of scans was 33mGycm, which corresponded to an average additional effective dose of 0.6mSv. Using the ImPACT CT dose calculator, it was determined that the average effect of reducing a scan by the average over-scan length resulted in an effective dose saving of 0.6mSv.

Discussion:
The increased requirement for optimisation of patient dose under the IR(ME)R 2017 regulations makes any simple change in procedure that reduces patient dose whilst maintaining image quality appealing. It has been shown that the average unnecessary effective dose associated with KUB scans at our institution is 0.6mSv; equivalent to the exposure of 30 chest X-rays. The fact that reducing scan length could reduce this dose without changing CT output parameters or reconstruction methods, with no sacrifice of image quality and diagnostic capability, motivates alteration of protocol.

[4] Shrimpton PC, Jansen JTM, Harrison JD. Updated estimates of typical effective doses for common CT examinations in the UK following the 2011 national review. Br J Radiol 2016; 89: 20150346

Measuring scattered energy spectra in Interventional Radiology; towards establishing clinically relevant energy response correction factors for eye dosimeters.
Seán Cournane¹, Maeve Masterson², Dani Maguire¹, Jackie McCavana¹, Julie Lucey¹
¹St Vincent's University hospital, Dublin, Ireland. ²National University of Ireland, Galway (NUI-Galway), Galway, Ireland

The radiosensitivity of the eye lens is a well-known phenomenon, with epidemiological studies having established the threshold dose for loss of eye lens function to be lower than previously considered. As a result, the International Commission on Radiological Protection (ICRP) has recommended that for occupational exposure an annual dose limit of 20mSv for the eye lens, averaged over defined periods of 5 years, should be applied with no single year exceeding 50mSv. This has been recently enacted into national legislation.

The most appropriate operational dose metric for monitoring the eye lens has been identified as the personal and directional dose equivalent at 3mm depth, Hp(3). Other suggested methods include evaluating Hp(3) through Hp(10) or Hp(0.07), both measured with dosimeters worn on the body trunk or Hp(0.07) dosimeters worn near the eyes. There are many uncertainties, however, associated with these dosimetry methods. In particular, the energy response for different dosimetry techniques may vary considerably depending on the incident photon energy spectrum. For Thermoluminescent Detectors (TLDs) the deviation of the energy response from unity is reported to vary by a factor of 0.9–2.5 in TLDs for Hp(0.07) and 0.9–1.6 for Hp(10) measurements. For both Optical Stimulated Luminescence Detectors (OSLD) and TLDs a dose overestimation occurs at lower energies, approximately in the 30-60kV range.

The energy dependence for commonly used Electronic Personal Dosimeters (EPD) may vary by a factor of 2.8 for the same energy range. Furthermore, for diagnostic radiology dosimeters the typical calibration energies employed tend to be at energies of 80kV or greater. While this kV value centres on the diagnostic radiology energy range and may prove useful for dosimetry of primary x-ray beams, the energy range does not correspond to those scattered energy spectra encountered in both interventional radiology and cardiology, which typically range between 30 and 60kV.

Studies examining the radiation dose levels received to the eyes of radiation workers for high dose procedures, in particular interventional radiology and cardiology, have reported that many physicians may potentially exceed the 20mSv annual occupational dose limit. The issue of the energy dependence of dosimeters in the clinical setting, and its effect on dose measurement accuracy whether Hp(3), Hp(0.07) or Hp(10) has received little attention in the literature; however the effect has been identified as the dominant
source of uncertainty in current eye dosimetry methods. There is thus a need to account for this uncertainty in order to provide an accurate means of measuring eye doses, so that staff can be protected and services not unnecessarily interrupted to the detriment of the patient. Accordingly, this study aims firstly to measure scattered x-ray energy spectra in Interventional procedures under varied conditions and system settings. Consequently, the dosimetry accuracy of a series of currently available eye dosimeters, including TLDs (100s, 100Hs), OSLD and Electronic Personal dosimeters (EPDs) will be evaluated with energy dependent correction factors then established for each dosimeter type, leading to more precise eye dose measurement.

Thursday 20th September, 11.00 – 12.30
The Future of Health Technology Assessment in Physics and Engineering in Medicine II

Introduction
Emmanuel Akinluyi, Guy’s & St Thomas’ NHS Foundation Trust & Alys Gilbert, Sherwood Forest Hospitals NHS Foundation Trust

This is a short introduction to the topics in the second part of the session, which focus on applications of HTA and challenges users have experienced.

Making an impact: Illustrating the role of Clinical Engineers in HTA through case study reviews
Dan Clark¹, Sarah Bolton² and Beth Beeson³
1. Clinical Engineering, Nottingham University Hospitals NHS Trust, Nottingham, United Kingdom
2. CHEATA - the Centre for Healthcare Equipment and Technology Adoption, Nottingham University Hospitals NHS Trust, Nottingham, United Kingdom

“Innovation Health and Wealth - Accelerating Adoption and Diffusion in the NHS” was published by the UK Government at the end of 2011 and is a hugely important strategy for all those interested in improving healthcare systems. This strategy made it clear that rapidly adopting innovative ideas and products is one of the best ways to improve quality and productivity and that these are clear priorities for the healthcare providers. It sets us this challenge: “Searching for and applying innovative approaches to delivering healthcare must be an integral part of the way the NHS does business. Doing this consistently and comprehensively will dramatically improve the quality of care and services for patients. It will deliver the productivity savings we need to meet the growing demand for services".

Healthcare providers clearly need new and innovative technology to provide improved health outcomes, improved efficiency, enhance the quality of life for people with long term conditions, prevent people from dying prematurely, help people recover from ill health and ensure that patients have a positive experience of care. Innovators and the MedTech Industry need help and support to get their ideas and research realised and adopted by healthcare providers.

The establishment of CHEATA (the Centre for Healthcare Equipment and Technology Adoption) was in direct response to this challenge. Our vision is to enable new medical technologies to be rapidly validated, evaluated and adopted into clinical practice thereby supporting the improvements to health outcomes, increasing the efficiency of healthcare delivery and supporting the growth of the medical technology industries.

Since its establishment, CHEATA has worked with over 100 clients and projects, providing a range of HTA support for medical technology. This presentation will review a number of these case studies, highlighting the role played by Clinical Engineers and, importantly, the impact made for industry, innovators and healthcare.
How to make evaluations and influence purchases  
Dr Saba Hinrichs-Krapels, Dr Harriet Boulding  
The Policy Institute at King’s, King’s College London

There is no doubt that purchasers, health professionals and tax-paying patients want the best value for money from medical equipment and supplies. Carefully assessing the purchase of new devices and technologies used in hospitals can help ensure a good deal, a sustainable purchase, and above all, the best available for the patient. However, the reality of achieving alignment of these requirements is challenging.

In this presentation, we demonstrate why there are challenges in achieving good purchasing and procurement in healthcare settings, particularly in NHS hospitals. Our observations are based on empirical qualitative data gathered across different NHS Trusts. We found that there is a high level of diversity in purchasing and inventory management processes, varying skills and capacities of those with purchasing responsibilities, and difficult conditions in which purchasing decisions are made. We also describe some of the strategies and workarounds that purchasers use to navigate these challenges – which both address and create difficulties. We end with our reflections on how we can use evaluations effectively and improve purchasing processes.

Breakout discussion / workshop  
Emmanuel Akinluyi, Guy’s & St Thomas’ NHS Foundation Trust & Alys Gilbert, Sherwood Forest Hospitals NHS Foundation Trust

The previous presentations will have highlighted the work that has already been done in the area of HTA that the audience may not be aware of. This interactive session will encourage the audience to consider how collaborating in HTA could work for them locally and the strategies that could be used to share evaluations and feedback in the future.

Scanning the horizon in HTA  
Dr Anastasia Chalkidou, King’s College London

Awaiting abstract

Thursday 20th September, 11.00 – 12.30  
Trainees I

First-steps in the automated classification of contributory factors in free-text NHS patient safety incident reports  
Haroon Chughtai 1,2, Saturnino Luz 3, Huw Prosser Evans 4, Peter Hibbert 5,6, Huw Williams 4, Aziz Sheikh 3, Liam Donaldson 7, Andrew Carson-Stevens 4,5,8

1UCLH NHS Foundation Trust, London, United Kingdom. 2University of Liverpool, Liverpool, United Kingdom. 3Centre of Medical Informatics, Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh, Edinburgh, United Kingdom. 4Primary Care Patient Safety (PISA) Research Group, Division of Population Medicine, Cardiff University, Cardiff, United Kingdom. 5Australian Institute for Health Innovation, Macquarie University, Sydney, Australia. 6Centre for Population Health Research, School of Health Sciences, University of South Australia, Adelaide, Australia. 7Department of Epidemiology and Public Health, London School of Hygiene and Tropical Medicine, London, United Kingdom. 8Department of Family Practice, University of British Columbia, Vancouver, Canada

Background: The principle of doing no harm is fundamental to the provision of safe, effective, and high-quality healthcare. Nevertheless, all healthcare systems experience errors, often avoidable, that can lead to...
patient harm. Patient safety is predicated on understanding why errors occur and using these insights to redesign care processes to reduce/mitigate risk to future patients. Such understanding is achieved through the analysis of incident reports at a system-level, a prerequisite of which is that incident types, severity, and contributory factors are robustly labelled.

Researchers have demonstrated the utility of these report data in the identification of a number of areas of service failure. However, the methods employed have involved time-consuming manual analysis of these data undertaken by expensive, trained analysts who extract the information locked in unstructured free-text fields. This means that these methods cannot easily scale from research institutions to healthcare organisations. Natural language processing (NLP) and supervised machine learning could provide a robust, automate, and inexpensive solution.

**Aim:** Work has previously been done on machine classifying incident types and severity, but the challenge is greater for contributory factors due to their more implicit representation. Contributory factors are the circumstances, actions or influences which are thought to have played a part in the origin or development of an incident or to increase the risk of an incident. These are the why of an incident and are vital for developing preventative actions. We therefore seek to develop and evaluate the practicality of using NLP and ML to identify contributory factors from free-text incident descriptions.

**Methods:** Our training data consisted of primary care patient safety incident reports (n ≈ 10,000), already expert-coded for contributory factors as part of a previous NIHR study. The free-text descriptions were pre-processed into a numerical form, before being used to train classifiers to discriminate between 27 contributory factors classes. F-score, precision, and recall were used to evaluate the classifiers’ performance.

**Results & Discussion:** We were able to demonstrate above baseline (i.e. data-weighted random assignment) performance using the report-derived input features, reaching an F-score of around 0.40 for the best SVM classifier. Around 40% of reports were correctly identified. Whilst this was not a clinically useful level of performance, it shows promise for the approach taken. We also found variation in performance between classes, showing that some contributory factor classes had more representative features than others.

**Conclusions:** Our work demonstrates that machine classification of contributory factors from incident reports is a viable route to follow. More sophisticated, domain-specific pre-processing, as well as consideration of relationships between contributory factor classes may be necessary to increase performance to a clinically acceptable standard.

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**Tissue Oxygen Saturation assessed in healthy volunteers with varying degrees of occlusion to their peripheral circulation – helping to understand the risk factors involved in Pressure Ulcer formation?**

**Emma Scott, John Allen, Gerard Stansby**
Newcastle University, Newcastle, United Kingdom

**Background:**
Pressure ulcers are common, debilitating and potentially avoidable. When tissue damage occurs, local inflammatory responses cause inflammation and swelling. This can lead to necrosis and ulceration. One risk factor for pressure ulcer is peripheral vascular disease. In order for inflammation and healing to occur, an adequate circulation is required. The aim of this pilot study was to assess tissue perfusion changes under simulated vascular impairment with objective measurements derived using tissue oxygen saturation (TOS) visible light spectrophotometry.

**Methods:**
Twelve adult healthy volunteers were studied in a temperature and light controlled room. After 10 minutes of acclimatisation, baseline TOS measurements (LEA O2C system) were taken from their right heel pad. A manual sphygmomanometer was positioned around their study ankle and with TOS measured at rest and after cuff inflation to 50%, and then 100% of their systolic BP for 1 minute (with 1 minute rest periods). TOS measurements were repeated 3 times and the mean values used.

**Results:**
Healthy volunteer TOS, 0% SBP occlusion TOS, 50% SBP occlusion TOS, 100% SBP occlusion
Conclusion:
Occlusion by 50% SBP reduced the saturation levels in all volunteers (mean 25.2%). Increasing from 50 to 100% SBP only dropped the saturation levels by a further 8.2% in the healthy volunteers. The presence of mild peripheral vascular disease or a state of reduced perfusion (i.e. any cause of shock) may significantly reduce the tissue saturation and thus healing potential, increasing the risk of ulcer formation.

Measurement of magnetic field correction factors of radiation detectors for the MR Linac
Pooja Gohil¹, James Agnew¹, Geoff Budgell¹, Ilias Billas², Simon Duane²
¹The Christie NHS Foundation Trust, Manchester, United Kingdom. ²The National Physical Laboratory, London, United Kingdom

Purpose: To investigate the effect of magnetic fields of differing strengths and in radiation beams of differing energies on ion chamber (IC) and diode detector response for use in MR linacs.

Methods: Measurements were made on a pre-clinical 7MV Elekta Unity MR Linac both with and without the 1.5T magnetic field present. A range of PTW ICs and diode detectors were positioned individually at isocentre (source-axis distance (SAD) 143.5cm), 10cm deep in water with stem axis parallel to the direction of the B-field, perpendicular to the beam direction, and irradiated with 100MU in a 10×10cm² field. Detectors were irradiated from gantry angles 90° and 270° and an average taken. For a subset of detectors, the measurements were repeated with stem axis oriented perpendicular to the direction of the B-field. The ratio of measurements at 1.5T and 0T $M_{1.5T}/M_{0T}$ was calculated for each radiation detector.

Similar measurements were performed using an electromagnet (range 0 – 1.6T) and Elekta Synergy linac at energies of 4, 6, 8 and 18 MV. Both the B-field strength and beam energy were varied to investigate the range of chamber responses. Measurements were at 5cm water equivalent depth & 306cm SAD. Detector stem axes were aligned perpendicular to both the B-field and beam direction in all cases.

Detectors investigated include PTW Farmer, SemiFlex, SemiFlex3D, Pinpoint 3D, Advanced Markus, Diode E, microDiamond, SRS Diode, as well as an IBA Farmer and Exradin A1SL.

Results: For measurements performed on the MR-linac in the parallel orientation, the deviation from the 0T reading ($M_{1.5T}/M_{0T} -1$) was in the range 1.4–1.8% for all cylindrical PTW chambers investigated here (PTW30013 waterproof Farmer 1.4%; PTW31022 Pinpoint 3D 1.8%). Diode response varied from 0.4% (Microdiamond) to 2.3% (SRS diode). In the perpendicular orientation, the response varied dramatically, from -9.6% (microDiamond) to +4.4% (PTW Farmer).

For measurements performed in the electromagnet, the ratio $M_B/M_{0T}$ varied with field strength $B$ for all detectors investigated here. For the diode detectors, the SemiFlex3D and Pinpoint 3D chambers, the readings recorded at non-zero B-field strengths were lower than those taken at 0T. For all detectors, increased beam energy resulted in a lower value of $M_B/M_{0T}$. For diode detectors, SemiFlex3D and Pinpoint3D this resulted in a larger deviation from the 0T reading, while for the remaining ICs this resulted...
Conclusion: Radiation detector response varies with beam energy and magnetic field strength. Small-volume ICs respond to the effect of increasing B-field strength and beam energy in a similar manner to diode detectors, indicating that the size of sensitive volume plays a part in the response of the detector in a B-field compared to measurements at 0T.

Design of computerised alignment system of lower limb prosthesis for Below-Knee Amputees
Edwin Khundi
University of Strathclyde, Glasgow, United Kingdom

Prosthetists use manual methods to fabricate and align artificial limbs with the body of a person with amputation. Computer-assisted alignment systems are still in infancy however some of the recently developed systems include: using a Compass system and manual adjustments, artificial intelligence and active robotic mechanisms. The limitation of the current system is that they still require the experienced prosthetist to manually adjust the components of the prosthesis. Thus the aim of this project was to design a computerized alignment system that can facilitate quick and accurate alignment process of the prosthesis for below-knee amputees. The proposed solution in this study is an alignment system consisting of an auto-tuning adaptor with six degrees of freedom in term of motion and also an associated application software. The software applications were designed using Python programming language and D-Flow application software. Figure 1a shows the user interfaces of the alignment application software. On the other hand, the auto-tuning adaptor consists of linear actuators, Arduino industrial 101 microcontroller, base plates, locking mechanism, and slots for sockets and pylon. The design specifications for the adaptor include a maximum range of motion =50mm, maximum force in struts =3000N, maximum base radius =60mm, and rotation =90 degrees. Figure 1b shows an image of the auto-tuning device. The auto-tuning device has markers that
can be tracked by a motion capture system. The coordinates from the Mocap module are used to calculate positions of the actuators and interpolate new positions to improve the alignment of the parts of the prosthesis and the body of the below knee amputee. The system was tested using computer simulation and is still being tested further in the laboratory environment. Thereafter the system will be tested in a clinical setting.

**Figure 1:** (a) The Python-based -alignment application software with guiding features for a bench, static and dynamic alignment of the below-knee prosthesis. (b) Auto-tuning device with six degrees of freedom.

The application software was functioning properly and the actuators were responding as required to achieve the required position and motion in all six degrees of freedom. As shown in table 1, the range of motion and force in the struts of the adaptor were also within the required safe loading ranges of not above 50mm and 3000N for the base radius of 30mm. In conclusion, the designed system is able to function properly and achieve designed positions. Future work will consist testing the system clinically in collaboration with experienced prosthetists. Once validated by the scientists, the system will be one of the computerised alignment systems of below-knee prostheses.

**Table 1:** (a) results of some parameters after simulating the device with a loading of 160Kg

<table>
<thead>
<tr>
<th>Base radius (mm)</th>
<th>Minimum length of struts (mm)</th>
<th>Maximum length of struts (mm)</th>
<th>Range struts change of length (N)</th>
<th>Minimum Force in the struts (N)</th>
<th>Maximum force in struts (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>84</td>
<td>131</td>
<td>47</td>
<td>680</td>
<td>2000</td>
</tr>
<tr>
<td>60</td>
<td>77</td>
<td>149</td>
<td>72</td>
<td>340</td>
<td>1000N</td>
</tr>
</tbody>
</table>

**Novel Phantoms for QC of In-house Developed Software in Nuclear Medicine**

Mark Pether
NHS Grampian, Aberdeen, United Kingdom

ImageJ is a free, open source image processing package with the ability to automate tasks through the development of macros. Locally ImageJ is used to process studies including gastric emptying and renograms. These macros are exempt from the Medical Device Regulations 2017 provided that a series of conditions are met. Among these is the requirement that the manufacture and use of the device occurs under appropriate quality management systems. There is little guidance within the nuclear medicine community for quality control (QC) of in-house developed software and so this work aims to formulate a QC procedure by constructing phantoms to produce images for testing.

For gastric emptying studies, a macro prompts users to draw regions of interest on a stack of coregistered planar images to calculate retention fractions. The primary requirement of the phantom was for the free movement of a radioactive bolus from a container emulating the stomach to another container emulating the small bowel. This was achieved by connecting a piping bag to a length of hose with an internal diameter of 16mm. The connection was made using a piping nozzle with tourniquets used to secure the bolus. The assembled phantom is shown in Figure 1.
A bolus of 300g of oatmeal was mixed with 20MBq of $^{99m}$Tc sodium pertechnetate and placed within the bag to represent the solid meal given to patients during a gastric emptying study. By weighing the bag and pushing the bolus through the phantom five series of 1 minute planar images were acquired on a Siemens Symbia Evo gamma camera. These series were designed to simulate normal, fast and slow emptying, complete retention and complete emptying. This allowed for limit and decision boundary testing of the retention fraction calculated by the macro.

Example normal images and retention fractions are shown in Figure 2 and Table 1. The retention fractions were within the desired normal or abnormal ranges for each of the different simulated cases.

![Figure 2](image)

<table>
<thead>
<tr>
<th>Image</th>
<th>Calculated Retention (%) (Relative to Image 1)</th>
<th>Desired Normal Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>70</td>
<td>30-90</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>0-60</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>0-30</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>0-10</td>
</tr>
</tbody>
</table>

Table 1

A similar project is underway to simulate renal drainage by constructing a kidney phantom, as shown in Figure 3.
Here a system of plastic containers, pipes and valves will be used to simulate different renal emptying situations. These images will then be used to test a macro which calculates NORA20, the retained activity in each kidney at 20 minutes relative to minute 2.

Images from these studies are now used as part of a QC protocol where quantitative metrics from ImageJ macros are calculated on a monthly basis and the results archived. A small tolerance of 2% has been set to account for inter- and intra-operator variation in the drawing of regions of interest. This work demonstrates a method to construct phantoms using inexpensive and widely available materials, which can be used to produce images for QC of quantitative in-house developed software.

Thursday 20th September, 11.00 – 12.30

**IGRT, Movement Management and Planning**

<table>
<thead>
<tr>
<th>A planning comparison of HyperArc and conventional coplanar VMAT techniques for the treatment of scalp lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nikki Laverick, Ronan Valentine, Peter Houston, Suzann Currie</td>
</tr>
<tr>
<td>Beatson West of Scotland Cancer Centre, Glasgow, United Kingdom</td>
</tr>
</tbody>
</table>

**Introduction**

HyperArc is a non-coplanar treatment solution developed primarily for stereotactic radiosurgery but which may also be beneficial in treating other sites, such as scalp lesions which often have a complex geometry. HyperArc offers practical advantages through shorter treatment times and lower collision risk, but may also have dosimetric benefits for this patient group by reducing the dose to healthy brain tissue.

**Methods**

Eight patients previously treated with radiotherapy for scalp lesions were replanned using both two axial coplanar arcs and HyperArc to a prescription of 65Gy in 30 fractions. In the creation of the HyperArc plan, automatic isocentre and collimator angle optimisation were utilised along with the SRSNTO within the plan optimisation.

All plans were normalised to cover 95% of the target volume with the 95% isodose line. Plan quality was compared in terms of maximum dose, dose to 99% and 2% of the target volume (D99% and D2% respectively). Dose to 10% (D10%) of the healthy brain tissue was also assessed, along with the mean dose to healthy brain.

**Results**

The target coverage was less homogenous when using HyperArc compared to coplanar arcs, with increases in D2% and maximum dose and a reduction in D99% observed across this patient group. However, there were also large reductions in the doses to the healthy brain tissue. Mean brain dose was reduced by an average of 9.2±1.6Gy and D10% was reduced by 15.8±1.1Gy. The reduction in the mean brain dose appears to correlate with the target volume, with a calculated Pearson correlation coefficient of 0.8 although this correlation is not observed for D10%.
Conclusions
In the treatment of scalp lesions, HyperArc can offer significant dosimetric benefits in terms of doses to healthy brain which are likely to have some clinical benefit for this patient group. When using this technique, the target coverage dose become more inhomogeneous, however this small disadvantage is outweighed by the larger dose reductions.

Dose De-Escalation for Oropharyngeal Cancer: A Treatment Planning Feasibility Study
Ronan Valentine, Suzanne Currie
Beatson West of Scotland Cancer Centre, Glasgow, United Kingdom

Aim: To evaluate the feasibility of dose de-escalation for oropharyngeal cancer by delivering a reduced dose to the elective PTV while assessing the impact on organs at risk (OARs).

Background and Introduction: Radiotherapy with radical intent for Head and Neck cancer can result in a significant amount of side effects due to redundant doses to OARs surrounding planning target volumes (PTVs). Dose de-escalation to the elective PTV is a promising prospect, which can circumvent unnecessary doses to important functional structures, therefore improving the quality of life for this patient cohort.

Materials and Methods: 10 patients, previously treated with VMAT as part of our clinical service were re-planned retrospectively using Eclipse TPS v15.5 [Varian Medical Systems, Palo Alto, CA, USA], RapidPlan® and multi-criteria optimisation (MCO). All plans consisted of two VMAT fields with two full rotational arcs at 6 MV and 600 MU/min. At the Beatson West of Scotland Cancer Centre (BWoSCC), Head & Neck cancers are typically prescribed to receive 65Gy in 30 fractions to PTV1 while the elective PTV, PTV_LR is treated to 54Gy in 30 fractions. The original clinical plans were re-optimised with a locally published RapidPlan® model to achieve optimal PTV coverage while maintaining OAR sparing consistent with our centre’s specified dose constraints. Subsequently, all plans were similarly re-optimised only this time PTV_LR was prescribed 40Gy (EQD2Gy) while retaining 65Gy to PTV1. Additionally, MCO was used to further optimise each plan in order to achieve additional improvements in OAR sparing for the 40Gy dose de-escalated prescription. Plan quality of V1_54Gy –vs– V2_40Gy plans was evaluated by assessing the dose differences between PTV1 and pertinent OARs such as the ipsilateral and contralateral parotids, larynx, submandibular glands, constrictor muscles and PRV (brainstem and spinal cord).

Results: PTV1 coverage as defined by our dose constraint form; D99%>90%, D95%>95%, D5%<105% and D2%<107% was achieved in each dose de-escalation case. Also, D99%>90%, D95%>95% and Dmean=40Gy ± 1Gy was achieved for PTV_LR. Furthermore, when comparing V1_54Gy –vs– V2_40Gy plans we found a reduction in the ipsi- and contra- lateral parotid mean dose of 3.4Gy and 4.8Gy, respectively. The mean dose to the larynx was reduced by 3.5Gy while the submandibular glands and constrictor muscles benefited from a decrease of 3Gy and 6Gy, respectively. Finally, a reduction in PRV brainstem (4.3Gy) was balanced against a slight, albeit within tolerance, increase in PRV spinal cord of 1.1Gy.

Conclusion: By reducing the dose from 54Gy to 40Gy (EQD2Gy) to the elective PTV, we found a considerable reduction in OAR doses while maintaining acceptable doses to both the primary PTV1 and elective PTV_LR. The encouraging results from this preliminary data have served as an impetus for us to increase the number of patients included in this retrospective treatment planning study. Dose de-escalation in Radiotherapy is an exciting step forward, which further interrogates that delicate balance of cure versus toxicity for patients presenting with oropharyngeal cancers.

Varian 4D CBCT initial analysis
Kathleen Roxby
Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, United Kingdom

Background
Use of 3D CBCT during treatment set-up is standard procedure for many radiotherapy treatments. 4D CBCT is an emerging feature in Varian linacs. With TrueBeam 2.5, 4D CBCTs can be taken in treatment mode, but only reconstructed in advanced reconstruction mode, limiting their use clinically. This work was
undertaken to examine 4D CBCT for the future when this functionality is fully integrated.

**Method**

4D CBCTs were taken of an in-house 4D phantom with different inserts. Different reconstruction parameters were investigated. Rods and spheres placed in inserts were used to assess signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), motion blurring and reconstruction accuracy for different amplitudes and frequencies of simulated breathing.

**Results**

The basic reconstruction mode was of insufficient quality to use. The advanced reconstruction mode gave suitable results, taking around 6 minutes to reconstruct. Repeated scans with the same parameters indicated minimal variability. A single scan may be reconstructed using different parameters many times, but the reconstructions must be separated manually upon import into the TPS. The same is true of different scans taken within the same treatment session. Generally, the SNR and CNR decreased with increasing breathing amplitude, and increased with increasing frequency. Motion blurring was fairly consistent. Compared to the 4DCT, the reconstruction accuracy at 0% phase was similar, whilst the 30% phase was worse.

**Conclusion**

The system needs to be better integrated to be used clinically. The advanced reconstruction may be suitable for clinical use in future versions.

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**A respiratory motion management strategy for both abdominal and thoracic VMAT radiotherapy**

Mark Bray-Parry, Joshua Gesner, Katrina Finnegan, Isabel Ho, Simon Stevens, Ashley Richmond, Jan Konieczek, Steven Critchley

The London Clinic, London, United Kingdom

**Purpose or Objective**

Thoracic and abdominal treatment sites can be affected by respiratory motion. When targeting with radiotherapy, it is important that this respiratory motion is accounted for. This is typically done by creating an ITV, determined by a 4DCT or extreme-phase breath-hold CT (i.e. end-expiration (EEB) and inspiration (IBH) CT). However, this approach can often lead to large volumes as the ITV needs to cover the entire extent of respiratory motion. Alternative approaches to minimise the respiratory motion include a breath-hold technique. The breath-hold from CT is replicated throughout treatment, and the uncertainty in breath-hold position is incorporated into a CTV–PTV margin. This study investigates a motion management strategy which aims to provide the optimal motion management technique for each individual patient. The strategy is shown figuratively in figure 1.
Material and Methods

43 patients who were assessed within our motion management strategy were reviewed. The patients included several abdominal and thoracic sites (predominantly pancreas, liver, lung, oesophagus, and mediastinum). For each patient, PTVs were generated using both ITV (PTVITV) and breath-hold (PTVBH) techniques. For ITV, a 5mm PTV margin was applied. For breath-hold, the breath-hold uncertainty during treatment was assessed and included on top of 5mm in the CTV-PTV margin. The volumes of the PTVs generated by both motion management techniques were compared.

Results

The difference in the PTV volumes between the two techniques varied, with a mean volume difference for all patients of 51cc (15% relative change) with a standard deviation of 52cc. For pancreas, the PTVBH was smaller in 7/11 patients with a mean reduction of 60cc (28.4%) and maximum of 143cc (35%). For 4/11 patients, the PTVITV was smaller by a mean of 23cc (17%) and a maximum of 64cc (13%). For liver, the PTVBH was smaller in 6/7 patients with a mean reduction of 93cc (14.9%) and maximum of 189cc (38.7%). For 1/7 patients, the PTVITV was smaller by a mean of 27cc (10.8%) and a maximum of 51cc (18.8%). For lung, the PTVBH was smaller in 4/7 patients with a mean reduction of 15cc (13.9%) and maximum of 38cc (46%). For 3/7 patients, the PTVITV was smaller by a mean of 27cc (10.8%) and a maximum of 51cc (18.8%). For oesophagus, the PTVBH was smaller in 2/6 patients with a mean reduction of 120cc (19.7%) and maximum of 124cc (23.9%). For 4/6 patients, the PTVITV was smaller by a mean of 52cc (14.6%) and a maximum of 85cc (10.4%). For mediastinum, the PTVBH was smaller in 1/5 patients with a reduction of 180cc (15.3). For 4/5 patients, the PTVITV was smaller by a mean of 12cc (4.5%) and a maximum of 14cc (5.6%).

Conclusion

The results show that the optimal motion management strategy to minimise the irradiated volume is patient-specific. While liver (PTVBH) and mediastinum (PTVITV) both showed a clear trend, both sites had a case where significant volume reduction was achieved by using the alternative technique. Therefore it’s important to have a flexible approach to motion management.

Assessment of the need for a change in imaging practice to achieve the margins in the PLATO trial

Ruth McLauchlan, Katie Perkins, Dolan Basak, Dorothy Gujral, Susan Cleator
Imperial College Healthcare NHS Trust, London, United Kingdom

Background.

Our Centre has recently changed on-treatment verification practice of patients receiving radiotherapy for anal cancer from planar kV to Cone Beam CT (CBCT) imaging. CBCT gives 3D volumetric information.
where soft tissue structures can be seen, specifically the soft tissue target structures of the gross tumour volume and lymph nodes, as opposed to planar imaging where the bony anatomy must be used as a surrogate for the position of these clinical target volumes. Verification images are taken on the first 3 fractions and then weekly with a combination of online and offline corrections used based on a bony match with adjustment for soft tissue if required.

The PersonaLising Anal cancer radiotherapy dOse (PLATO) trial utilises a smaller clinical target volume (CTV) to planning treatment volume (PTV) margin than is standard practice in our Department: 0.5 cm compared with 1.0 cm. The use of a 0.5 cm CTV to PTV margin for the nodal volumes is from the National Guidance for IMRT in Anal Cancer document (www.analimrtguidance.co.uk) with the note “These margins are appropriate for patients treated with daily online imaging. We recommend centres audit their local set up regularly”. An audit was performed of our local set up to ensure that the 0.5 cm margin is appropriate for our patients.

Methods.
The CBCT images for 20 consecutive patients were reviewed by a single, experienced observer. An automatic bony match was used to evaluate the shift in treated from planned position and coverage of the CTV by the PTV was reviewed. The population random and systematic errors were calculated following the method described in the “On target” document and entered into the van Herk margin recipe to obtain the CTV-PTV margin. Individual graphs of shift in target position at each fraction of treatment for each patient were generated to help determine if more frequent imaging should be considered than is current Departmental practice.

Results.
In total 143 CBCT scans were reviewed. Median shift values for individual patients were less than 0.5 cm in all cases but overall around 10% of shifts were ≥0.5 cm from the planned position. Population random and systematic errors are given in the table below along with the resulting margins from the van Herk formula.

<table>
<thead>
<tr>
<th></th>
<th>AP</th>
<th>SI</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Σ [cm]</td>
<td>0.17</td>
<td>0.16</td>
<td>0.13</td>
</tr>
<tr>
<td>Population σ [cm]</td>
<td>0.20</td>
<td>0.21</td>
<td>0.25</td>
</tr>
<tr>
<td>Van Herk Margin [cm]</td>
<td>0.56</td>
<td>0.54</td>
<td>0.51</td>
</tr>
</tbody>
</table>

In all cases the CTV was covered by the PTV without the need for soft-tissue adjustment but this should be re-evaluated for a reduced margin of 5 mm. Individual graphs of shift in target position at each fraction for each patient demonstrated that it cannot be predicted when during treatment a shift in position will take place.

Conclusion.
Our analysis indicates the current margin of 1.0 cm is safe with our current imaging protocol. To reduce the margin to 0.5 cm requires an increase in imaging as advised by the PLATO trial team. It is suggested that the PLATO minimum imaging requirement of CBCT for the first 3 fractions and weekly with additional kV planar imaging for all other fractions is implemented and the audit repeated following this change in practice.

Reconstructing patient breathing traces 'played' by the CIRS MRI-Linac Dynamic Phantom using an image based method
Steven Jackson, Michael Dubec, Glyn Coutts
The Christie NHS Foundation Trust, Manchester, United Kingdom

Background
The hybrid MR-Linac machine offers the potential for adaptive radiotherapy treatment, with MR imaging informing the treatment beam in real-time\(^1\). For lung cancer patients, a 4D imaging dataset is acquired to inform radiotherapy treatment planning and relies on a suitable patient breathing trace being available\(^2\). The CIRS MRI-Linac dynamic phantom is designed to commission 4D imaging and 4D radiotherapy systems\(^3\). It consists of a large fluid filled main body with a hole through which an MR-invisible insert, containing a small chamber of MR visible gel, can be moved in and out and rotated with high precision.

**Aim**
The aim of this study was to assess the potential to reconstruct a breathing trace using MRI images of the phantom taken whilst it 'played' a breathing trace acquired from patient data.

**Method**
A lung patient breathing trace was obtained via an edge detect method on a dataset comprising 120 single slice, coronal, 2D, balanced steady state gradient echo images acquired as a cine on a clinical scanner. The resulting breathing trace was loaded into and 'played' by the CIRS MRI-Linac dynamic phantom. A multi-slice, 2D, coronal, balanced steady state MR acquisition was acquired across the gel-filled chamber on the MR-Linac. The breathing trace of this chamber across multiple slices was reconstructed using an edge detect method applied to the images in post processing.

The resulting breathing trace was compared with the input breathing trace on a point by point basis, following suitable interpolation, see figure 1. The \(R^2\) correlation and the maximum discrepancy between the two signals was calculated for twelve patients, each with three repeats. Sinusoidal waveforms of two periods were also 'played' and imaged to baseline the more complex patient breathing traces, again with three repeats.

![Figure 1: input waveform (blue) and measured breathing trace (red).](image)

**Results:**

Sinusoidal waves, \(n=6\) (two acquisitions, three repeats)
- Mean \(R^2\) correlation = 0.976 ± 0.011 (standard deviation)
- Mean max discrepancy = 3.85 ± 0.55mm

Patient breathing traces, \(n=36\) (12 acquisitions, three repeats)
- Mean \(R^2\) correlation = 0.934 ± 0.044
- Mean max discrepancy = 3.54 ± 0.86mm

**Discussion**
The results showed excellent correlation between a sinusoidal input motion and its measured position and very good correlation between the input and measured patient breathing traces. The maximum error was under 4mm throughout. If the chosen reconstruction method were to be used to reconstruct a 4D-MR dataset for the purposes of radiotherapy treatment planning, a lower maximum error would be desirable.

**Conclusion**
Arbitrary patient breathing traces were reconstructed with good accuracy using an image based, post-processing method applied to 2D MR images.

**References:**
Thursday 20th September, 13.30 – 15.00

Big Data in Healthcare

Artificial Intelligence in Healthcare
Tim Adlam
Designability, Bath, UK

Artificial intelligence (AI) is here, and not yet here; but what is it, and is it useful in healthcare? We will look at what it is, how it’s useful now, how it might be useful in the future, and think about important issues like “how do we make sure AI in healthcare is safe?”. We don’t have all the answers yet, but it’s coming anyway, and it’s probably in your pocket right now.

We have seen artificial intelligence in movies for a long time, and we’re used to ideas of rogue robots and systems causing all manner of difficulty and destruction. However, in reality, AI is arriving in much more narrowly defined contexts than the broad capabilities science fiction might suggest. Serious thinking about AI began in the mid-20th century, and has been developing ever since, but recent advances in technology have heralded its arrival in our pockets and living rooms; and now in our hospitals and healthcare providers too.

AI is able to do many useful things in a healthcare context, across a broad swathe of applications from surgery to health monitoring and emergency care. For example it is analysing images and heart beats, and providing support for people with mental health problems. We will think about why we might or might not want AI to be more deeply implemented in our own healthcare services, look at some existing healthcare applications, some opportunities for future applications, and discover the approach to AI and robotics being taken in the CHIRON project led by Designability. We will also think about how we might approach safety and risk in medical devices with learning AI built in. It’s not straightforward, and research in this area much needed.

Radiotherapy data mining in clinical practice – data and governance infrastructure
John Lilley1, Appelt Ane2, Bob Wheller1, Carole Burnett1, Ann Henry2
1Leeds Cancer Centre, Leeds, United Kingdom. 2University of Leeds, Leeds, United Kingdom

There is increasing interest in the use of routinely collected radiotherapy data to inform clinical developments and treatment of future patients. For this to work efficiently and successfully, it is essential that the appropriate infrastructure and research governance is in place. Such structures should preferably be set up so that 1) comprehensive data collection can happen automatically, without impact on clinical databases and service; 2) information governance supports quick research project approval, does not impact on routine data use (e.g. for service planning and internal reporting), and fulfils all formal IG requirements, including appropriate access to sensitive, patient identifiable data; 3) external collaboration is simple and risk-free with respect to IG.

We are creating such a setup, to allow research on routine clinical data. A separate server holds a repository of tables from the record and verify and scheduling systems as well as the electronic patient record system; this server is updated nightly outside of clinical hours. It links to our mini PACS, which contains a record of all radiotherapy-related image data and treatment plans. This server has historically been used for routine reporting of radiotherapy data and internal reporting relating to workflow, but is now being set up to support data mining research, including software tools for automatic data anonymization, for data review & cleaning, as well as for advanced image analysis. Working with our local Research &
Innovation and Information Governance departments, we are setting up a research governance framework such that research projects may have a simple approval process. The final part of this data mining setup is the addition of a distributed learning and data sharing environment, to allow for national and international collaborations. The distributed learning methodology ensures that outcome models can be developed and tested across multiple centres without any patient data leaving the individual institution.

Data and knowledge generated in each separate research project will be fed back into the server, to increase the useful data available for future projects.

We aim to learn from patients previously treated outside of traditional clinical trials and use that information to design the future protocols and ultimately individualised treatment.

### A ‘Big Data’ analysis of radiotherapy beam output measurements. Do constancy devices under report beam output?

Matthew Bolt$^{1,2,3}$, Tao Chen$^2$, Catyline Clark$^{3,1}$, Andy Nisbet$^{1,2}$

$^1$Royal Surrey County Hospital, Guildford, United Kingdom. $^2$University of Surrey, Guildford, United Kingdom. $^3$National Physical Laboratory, Teddington, United Kingdom

#### Background

Beam output is routinely measured for radiotherapy treatment machines to ensure consistency of delivered doses. Measurements are often taken daily using a constancy device and weekly using a Farmer chamber. Ideally measurements from the constancy device would match those from the Farmer exactly to allow the best informed decisions relating to beam output to be made.

#### Method

Farmer chamber and constancy device measurements of beam output were collated for 99 treatment machines spanning 6 months. If there were fewer than five results for each device on a machine then these were excluded, leaving 95 machine datasets across 29 radiotherapy centres. A breakdown of datasets is given in Table 1.

<table>
<thead>
<tr>
<th>Device Manufacturer</th>
<th>Device Model</th>
<th>Number of centres</th>
<th>Number of Treatment Machines</th>
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<tbody>
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<td>Various</td>
<td>Farmer Chamber</td>
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<tr>
<td>SNC</td>
<td>Daily QA3</td>
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<tr>
<td>ScandiDos</td>
<td>Delta 4</td>
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</tbody>
</table>

Table 1: Dataset summary

For each machine the data was corrected for beam calibrations. The difference in the mean beam output as measured by the Farmer chamber and constancy devices was then determined. The distribution of these differences was then analysed as a whole and based upon individual device types to determine any statistically significant difference from an expected zero difference between device types using a t-test. In this work the beam output is given as a percentage deviation from the expected value.

#### Results

On five machines the mean difference in measured output between the constancy device and Farmer chamber measurements was greater than 1%, and 28 exceeded 0.5%. Of the 95 machines, 65 (68%) had a mean Farmer reading greater than that of the constancy device. The mean difference between Farmer and constancy devices was +0.23% (indicating Farmer results showed a higher beam output). This was found to be statistically significant to the ideal value of zero difference ($p<0.01$). The maximum differences were +1.3% and -0.9%. Figure 1 shows the distribution of results.
A strong correlation between the mean of measurements taken with Farmer and constancy devices was observed with a Spearman's correlation coefficient of 0.86 (p<0.001) and $R^2$ of 0.73. This indicates good corroboration between the magnitudes of measured beam outputs with different devices.

Conclusions

A statistically significant difference between the mean of beam outputs measured using Farmer chambers and constancy devices has been identified through the analysis of beam output measurements from 95 treatment machines. The Farmer results reported a beam output $+0.23\%$ greater than the constancy devices on average. In some cases large differences were seen in measurements made by different devices on a single machine, however a range of tolerances for this difference are used in clinical practice. In clinical practice it is most common to use a single set of measurements to compare measured output readings from different devices, however this may not adequately identify the true offset. Further investigation is required to determine the cause for the systematic offset observed.

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IBM Watson and AI in Healthcare

Kyu Rhee, IBM Watson Health

Awaiting abstract

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Thursday 20th September, 13.30 – 15.00

Trainees II

VMAT Planning for the Internal Mammary Chain

Dina Roshd, Charlotte Westbury, Karen Venables
Mount Vernon Cancer Centre, Northwood, United Kingdom

In November 2016 the Royal College of Radiologists (RCR) published a consensus statement which strongly recommends that irradiation of the Internal Mammary Chain (IMC) be considered for breast patients at high risk of locoregional recurrence [1]. At our centre, our current practice is to treat a breast, lymph nodes and IMC using the partially-wide tangent technique. Spurred by the RCR’s recommendations,
we undertook a planning study whose aim was to develop an alternative VMAT technique. And during this study, we addressed three questions in particular.

**Which arc geometry is most suitable for our system?**
At our centre, we are equipped with Varian linacs and the Eclipse treatment planning system (TPS). We investigated two types of arc geometries — the first known as the ‘bow-tie’ geometry, the second resembling a ‘crescent’ geometry (see figure) [2,3]. We found that the bow-tie plans suffered from poor conformity, whereas the crescent plans benefited from markedly improved conformity. To understand why, we analysed each arc in our crescent plans in terms of (1) the open-area defined by the MLCs and (2) the MU delivered, both as a function of the gantry angle. We found that, significantly, one of the crescent arcs made a non-negligible contribution to the dose distribution from directions perpendicular to the chest-wall. Our results support the suggestion [4], often overlooked, that the optimal arc geometry is both linac- and TPS-dependent.

**How can we ensure that our plans are robust?**
The IMC PTV, by definition [5], extends into the low-density lung. There is currently no consensus amongst radiotherapy planners as to whether a low-density region in a PTV should be overridden to the density of water during optimisation. Here we investigated a novel compromise solution, which consists in overriding the low-density region in the IMC PTV to 0.5 g/cm$^3$ [6]. And we tested the robustness of our plans by shifting their isocentre by 0.5 cm anteriorly. We found that, without any density override, the maximum dose over the IMC PTV increased by ~7% when the isocentre was shifted. In contrast, with a density override of 0.5 g/cm$^3$ during optimisation, the maximum dose increased by only ~1%.

**How can we ensure that our plans are deliverable?**
At our centre, we routinely immobilise breast patients on an inclined breast-board with both arms raised. With such immobilisation, we must take care to preclude any collision between the patient’s contra-lateral elbow and the linac head. Here we introduced a novel method for achieving this. The method involves creating a ‘virtual elbow’ structure in the CT dataset, and then using the arc geometry tool in the Eclipse TPS to determine the optimum position of the isocentre that avoids collisions.

In conclusion, our planning study revealed that (1) a crescent-shaped arc geometry is optimal for our specific combination of linacs and TPS, (2) a density override of 0.5 g/cm$^3$ in the low-density region of the IMC PTV improves the robustness of our plans, and (3) the creation of a ‘virtual elbow’ precludes collisions.
Background. Stereotactic Ablative Body Radiotherapy (SABR) is a hypofractionated treatment technique for extra-cranial tumours, delivering radical doses in fewer fractions than standard treatments. With higher doses per fraction, steep dose gradients and small tumour volumes, high treatment delivery accuracy is required to ensure successful treatment outcomes. This study aimed to develop a film dosimetry based quality assurance (QA) procedure to verify the accuracy of SABR treatments for peripheral early-stage lung tumours.

Methods. GafchromicEBT-XD, an extended dose range self-developing film, was used for dose measurement due to its accuracy in handling steep dose gradients with high spatial resolution. An absolute dose calibration of the film was performed with doses ranging from 200 to 3600 cGy, using 6MV on a Varian TrueBeam, and scanned 24 hours post-exposure with an Epson Expression 10000XL flatbed scanner. DoseLab was used to obtain Optical Density (OD) images, and create a calibration file relating OD to dose. The minimum number of dose levels required to create a valid calibration curve was evaluated. The minimum time required between exposure and scanning was investigated to aid workflow. Film was irradiated with 600 cGy and scanned over time to assess when the OD stabilised. Nine lung tumour patients, retrospectively planned using four 6MV partial arcs, were used in this study. These plans were delivered to the Quasar Respiratory phantom in static mode with film secured within the lung insert. The film was scanned and converted to dose images in DoseLab, and compared with the calculated dose planes from RayStation treatment planning system. A patient-specific QA (PSQA) protocol was devised incorporating film measurements and subsequent analysis.

Results. A minimum of 9 dose levels were required to ensure successful calibration, with an optimum scanning time post-exposure of 21 hours. Using this calibration, 8 out of 9 patient plans passed 3%/3mm gamma analysis criteria (global, $\gamma<1$, 95% pass rate, 10% threshold), with a 98.4% average pass rate. Measured and calculated distribution line profiles were compared; the mean shift for optimal positioning in the X- and Y-directions was calculated as 0.37mm and 0.50mm for right lungs, and 2.5mm and 0.34mm for left lungs.

Discussion. Film dosimetry results were compared with other established verification methods including Delta4 and independent dose checks using RadCalc, showing good agreement of results. Good dose agreement with ion chamber measurements and RayStation dose planes indicate the calibration was successful. Variations in film positioning during scanning directly impacted the resulting measured dose; these variables were evaluated and the protocol modified to reduce errors. The optimal positioning of the line-profile indicated a systematic error in positioning for all left lung films. This is under investigation and attributed to the location of the fiducial mark as specified in RayStation.

Conclusion. A PSQA procedure to verify the accuracy of lung SABR treatments was successfully developed using GafchromicEBT-XD film, Quasar phantom and DoseLab. Lung SABR has recently been implemented in the department with PSQA successfully performed for the first 2 patients. Future work will investigate process-based gamma tolerance levels and develop this procedure for dynamic measurements.
Methods. We developed a methodology for extrapolating the range of electron beams through water and tissue phantoms (adipose, bone and lung) using the Monte-Carlo particle tracking toolkit Geant4 and a fitting method based on a Fermi-Dirac equation detailed in the report. We verified the use of Geant4 for range analysis in the reproduction of ICRU data for the range of protons in water using similar percentage dose-depths curves over the energy range 50 – 250 MeV with analysis made on goodness of fit and comparison with ICRU data².

Results. 90% and 50% ranges (range where dose is 90% and 50% of the maximum respectively) were obtained from the proton percentage depth-dose (PDD) curves and compared with ICRU data³. Of the two, the Geant4 90% range was the best fit, agreeing with the ICRU range data to within 0.18%. Extrapolated ranges for electrons were calculated over the clinical energy range (50 – 250 MeV) to produce an analytical expression for electron range depending on energy and material properties (atomic mass and density). Such an analytical expression allows the comparison of proton and electron ranges over similar energies.

Discussion. The percentage errors from the proton results clearly indicate the suitability of Geant4 for measuring the range of proton beams in matter and so electron beams with suitable modification. The Fermi-Dirac equation proved a very accurate fitting method for the electron PDD curves and allowed measurement of the extrapolated ranges over the clinical energy range. Results clearly indicated that, as with protons, electrons are dependent on the density and effective atomic mass of the phantom material.

Conclusion. On verification of proton range data, Geant4 was used to produce PDD curves of VHEE from which the extrapolated range was measured and used to produce analytical expressions for range in various media. Such simulations are the first of their kind and we hope that they will have an application in the development of an accurate, precise treatment planning system for very high-energy electron therapy.

References.

4D-MR from clinically available pulse sequences - a feasibility study
Steven Jackson, Michael Dubec, Glyn Coutts
The Christie NHS Foundation Trust, Manchester, United Kingdom

Background
42% of Small Cell Lung Cancer Patients receive radiotherapy as part of their treatment¹. A 4D-CT imaging dataset is acquired to inform radiotherapy treatment planning for these patients and relies on a suitable patient breathing trace being available². 4D-MR has the potential to complement or supersede 4D-CT due to its superior soft tissue contrast³. Many pulse sequences for 4D-MR exist, but are not yet available on clinical scanners without significant post processing or pulse sequence programming⁴-⁵.

Aim
The aim of this study was to attempt to reconstruct a 4D-MR dataset out of clinically available pulse sequences in under 5 minutes of scan time.

Method
A stack of 2D, coronal, balanced steady state gradient echo acquisitions were acquired for eleven patients, with ethical approval granted as part of Clinical Trial NCT03048760. A breathing trace was acquired from the resulting image data using an edge detect method across the lung liver boundary. The individual frames acquired were allocated to 4D datasets using both amplitude and phase binning based on the acquired breathing trace. The number of 4D dataset bins successfully filled with imaging data was recorded for both amplitude and phase binned reconstruction methods. A distinction was drawn between acquisitions comprising 24 slices with 35 repeats and 12 slices with 60 repeats.
Maximum Intensity Projections (MIPs) across the breathing phases were rigidly registered to equivalent 4D-CT MIP reconstructions of the same patients, also acquired as part of the above trial. A quantitative comparison of prominent features was undertaken.

**Results:**

<table>
<thead>
<tr>
<th>Slices (acquisitions)</th>
<th>Mean amplitude binning fill success (% ± standard deviation)</th>
<th>Mean phase binning fill success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24(35), n=7</td>
<td>60.8 ± 8.8</td>
<td>96.8 ± 2.5</td>
</tr>
<tr>
<td>12(60), n=4</td>
<td>90.5 ± 6.1</td>
<td>100 ± 0</td>
</tr>
</tbody>
</table>

The coverage of the 4D-MR scans was limited by acquisition time available.

**Discussion**

The results show that phase binning is a more successful reconstruction method than amplitude binning using a 4D from 2D slice stacking method. Increased acquisition time would allow for more coverage but this was beyond the study scope. The 4D-MR and 4D-CT MIP patient datasets show good agreement between known features such as liver profile following rigid registration. The method suggests a test of the 4D-MR reconstructions to inform radiotherapy treatment planning contours would be warranted.

**Conclusion**

4D-MR using clinically available pulse sequences is feasible with reduced coverage compared to 4D-CT over a 5 minute acquisition.

**References:**


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**Dosimetric Investigation and Optimisation of Liver Radioembolisation Using 90Y Microspheres**

Sarah Williams, Caroline Findlay, Clare McKeown, Gerry Gillen, Ram Kasthuri, Sai Han
NHS Greater Glasgow and Clyde, Glasgow, United Kingdom

**Introduction**

Selective internal radiation therapy (SIRT) for treatment of primary liver cancer and hepatic metastases involves delivering microspheres, labelled with Yttrium-90 (90Y), for radioembolisation in the liver. The activity of 90Y administered is calculated using the measured target liver lobe volume. These volumes are measured using diagnostic CT images and/or 99mTc-MAA (macro aggregated albumin) Single-Photon Emission Computed Tomography/Computed Tomography (SPECT/CT) images, however, there is currently no gold standard. This project compared two volume measurement methods to determine which was the more accurate measure of the final treatment volume.

For SIRT, prospective dosimetry is unknown; however, retrospective dosimetry using post-therapeutic imaging is possible. An accurate pre-therapeutic dosimetry predictor may benefit the procedure. This project assessed whether dosimetry for SIRT can be accurately predicted using the 99mTc-MAA post-therapeutic images as a surrogate for Therasphere distribution using the post-therapeutic dosimetry for comparison. Finally, the feasibility of dosimetry using post-therapeutic images was evaluated to determine if measured doses correlate to prescribed doses.
Methods

Firstly, two phantom studies were performed to validate the software used for liver lobe volume measurements; the measured and actual phantom volumes were compared to determine the measurement error. This error was applied to an assessment of two liver lobe volume measurement methods.

An anonymised observer study was carried out comparing volume measurements calculated using diagnostic CT and 99mTc-MAA SPECT/CT. These were compared to volume measurements obtained from the 90Y post-therapeutic Bremsstrahlung SPECT/CT images to determine which was the better indicator of treatment volume. The volumes were calculated by five operators for a sample of seven liver lobe treatments, facilitating measures of intra and inter-operator variability. The percentage difference between both techniques and therapeutic distribution was calculated. The Wilcoxon signed-rank test (WSR) was used to measure statistical significance between volume calculations.

Dosimetry was performed using pre-therapeutic 99mTc-MAA SPECT/CT and post-therapeutic 90Y Bremsstrahlung SPECT/CT images to establish if pre-therapeutic images can be used to predict SIRT doses. Two dosimetry methods were utilised: MIRD schema dose calculations and dosimetry software, Simplicity. Finally, the doses obtained using post-therapeutic 90Y Bremsstrahlung SPECT/CT images were compared to prescribed doses to investigate the feasibility of post-therapeutic dosimetry.

Results

The results demonstrate that there is no statistically significant difference in volume measurements made using diagnostic CT (p-value=0.4) or 99mTc-MAA (p-value=1) with the 90Y-Bremsstrahlung volumes. However, the 99mTc-MAA demonstrates a stronger correlation and smaller percentage difference range with the therapeutic distribution (CT=12.12%, 99mTc-MAA=3.06%).

The assessment of dosimetry demonstrated that doses calculated using pre-therapeutic images and post-therapeutic images were not statistically significantly different. There is also a high correlation between post-therapeutic calculated and prescribed doses.

Conclusion

This research indicates volume measurements should be performed using 99mTc-MAA SPECT/CT images. However, a combination of techniques and interventional radiologist knowledge of hepatic vasculature should be used as guidance to liver anatomy. This project established that 99mTc-MAA SPECT/CT images can be used as a reasonable pre-therapeutic predictor of 90Y SIRT dosimetry. Finally, post-therapeutic images can be used to accurately measure post-therapeutic dosimetry.

Monte Carlo modelling and experimental measurements of range uncertainties in proton therapy associated with sub-CT resolution heterogeneities in bone and lung

Sumaira Nazir¹, Richard Hugtenburg¹,², Paolo Pellicioli¹, Nathan Kimball-Smith¹, Jordan Pritchard¹, Tony Price³

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The scattering of protons through heterogeneous material leads to a broadening of the range along straight ray-paths that is a consequence of the differing paths that the proton can take through media. The effect has been demonstrated in bone and lung models with the FLUKA Monte Carlo code and experimental measurements with a 29MeV proton beam.

The bone-substitute material, SawBone, ranging in density from 0.088 to 0.48 g/cm³, was used to simulate bone and lung heterogeneities. Micro CT and MRI images were obtained of the SawBone material and the former was used to construct Monte Carlo models of realistic proton radiotherapy treatments and to benchmark experimental studies (Figure).

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Figure. Broadening of a 100 MeV proton beam traversing the cortical and trabecular bone in the skull plate and a Monte Carlo experimental benchmark with the bone-substitute, SawBone.

Broadening of the Bragg peak and shifts in the range, as defined by the D20% depth-dose parameter were observed both experimentally and in Monte Carlo models, indicating that such effects are in principle, clinically relevant in certain circumstances. A novel MRI sequence was used to characterise the structure of the bone-substitute and analysis suggests that in practice MRI may be able to be used to quantify sub-CT
Future Procurement and Service Models in the NHS

New Operating Model for NHS Supply Chain
Jim Craig, Programme Director
Jo Gander, CaPA Director
Supply Chain Coordination Limited Management Function of NHS Supply Chain

The NHS Supply Chain Procurement Transformation Programme (PTP) is delivering a new business operating model that will deliver savings of £2.4 billion across NHS organisations that can be reinvested into frontline services. The on-time delivery of supplies to NHS Trusts is critical to patient safety. The PTP is delivering efficiencies and reducing costs whilst ensuring that the delivery of services to the frontline is seamless.

In February 2016, Lord Carter’s report into efficiency and productivity in the NHS identified unwarranted variation in procurement across the NHS resulting in the need to improve operational efficiencies to help transform an already fragmented procurement landscape. The PTP was established by the Department of Health and Social Care, to undertake this transformation and deliver a new NHS Supply Chain.

The PTP is delivering a new operating model, replacing the existing NHS Supply Chain contract with DHL Supply Chain Limited by March 2019. The new operating model ensures NHS needs and objectives are at the heart of the delivery, providing consistent product pricing and increasing product range optimisation across the NHS, increasing value for money and providing more consistency in both clinical and patient experience.

Developing increased training capacity – an initiative in medical physics in London
Clare Anderson¹,², Sarah Peel³,², Gillian Clarke⁴, Andy Irwin⁵, Claire Hardiman⁶
¹East and North Hertfordshire NHS Trust, London, United Kingdom. ²Health Education England, London, United Kingdom. ³Guy’s and St Thomas’ NHS Foundation Trust, London, United Kingdom. ⁴King’s College Hospital NHS Foundation Trust, London, United Kingdom. ⁵St George’s University Hospitals NHS Foundation Trust, London, United Kingdom. ⁶Imperial College Healthcare NHS Trust, London, United Kingdom

Background: Expressions of interest for Medical Physics STP training posts in London are restricted by the training capacity of host centres. There is a need for new initiatives to help increase the number of training places, in line with recommendations of the Independent Cancer Taskforce Report[1] and IPEM position statement on the Radiotherapy physics workforce[2] which states that ‘all training centres should be training at their capacity’ and that ‘the supply of trained staff to provide physics support to radiotherapy is barely adequate for the current service, and inadequate for the planned service expansions’.

From 2016, HEE (North Central and East London) funded an education project to increase capacity and capability for Medical Physics and Clinical Engineering STP training in London to address the workforce shortages.

The objectives were to:

- Improve the training infrastructure by increasing the number and effectiveness of those involved in training
- Train extra staff in departments across London to enable more staff to assess competencies
- Provide local practical assistance to departments in delivery and assessment
- Organise workshops to enable some elements of rotational and specialist placements to be delivered and assessed
Oversee generic competencies

Develop ideas for patient and public involvement in STP training

Methods:

> Final year STP trainees were interviewed to identify areas of the training that require improvement and streamlining

> STP supervisors’ days were devised and delivered to enhance STP supervision and develop new trainers. Trainer development days were used to develop consistent training approaches and explore ways that training centres could collaborate on training

> Collaborative practical assessed workshops were developed and delivered to fulfil niche areas of the curriculum. These included; MRI safety, brachytherapy, non-ionising radiation techniques and lasers

> Regional tutors supported trainees to fulfil professional practice competencies

> Local train the trainer events were held in various clinical departments focussed on local needs

> Feedback was collated on the MSc curriculum, IPEM guidance and NSHCS learning guide

Results and Conclusion: Since June 2016, regional tutors have provided additional support to STP training, resulting in a commitment to extra training places in London from September 2018. We will share our model of supporting increased regional training capacity and describe further work.


Teaching Radiotherapy Physics to student Radiographers using VERT™ Physics - an update of four years’ experience

Mike Kirby
Directorate of Radiotherapy, University of Liverpool, Liverpool, United Kingdom

Radiotherapy Physics is a challenging subject – especially when teaching it across disciplines. For example, for therapy radiographer students, whose primary role is entirely patient focused, it is vital to their fundamental understanding of radiotherapy, but amidst a wide range of clinical, empathetic, technical and other skills needed for successful treatment. Finding ways, therefore, of teaching fundamental Physics concepts, in a new and engaging manner helps to establish deep learning for developing excellent clinical practice, but also brings an appreciation of the equal rigours of other disciplines involved in effective radiotherapy. Such understanding leads to solid collaboration and interprofessional working in research and development for advancing cancer treatments.

The use of a Virtual Environment for Radiotherapy (e.g. VERT™) is one way we have found that helps students engage better and more fully in learning and understanding key Radiotherapy Physics principles, in an interactive and dynamic manner, without needing precious Linac time and with all the benefits of the virtual environment……most notably to gain viewpoints inside, outside and around objects which are just not possible in the real world.

We have used VERT™ Physics, a specialised module within VERT™, successfully for over four years now at the University of Liverpool in both 2D and 3D immersive modes to teach fundamental concepts to undergraduate and postgraduate radiotherapy students. First formats used small group sessions blending lecture and practical use of the software, which then changed to a practical only basis in the following format. Concepts examined included dosimetric consequences of FSD set-up error; QC photon beam energy checks and the derivation of field size factors. For each subject area, workbooks were provided for all; one group would perform the experiments practically on VERT™, whilst the other would use whiteboards to perform calculations to predict results which were confirmed with VERT™ Physics. Evaluation and feedback was excellent, especially regarding the small group methods; the results of which have been previously published [1].

The format has now evolved into using VERT™ Physics for practical (interactive) demonstration of percentage depth dose data; how it is acquired and verified, and the concepts of independent data sets. The learning is blended, involving expert tuition and peer-to-peer learning again with students.
discussing and predicting effects between themselves on whiteboards (such as changes in fieldsize, energy, FSD) and then confirming predictions using the VERT™ Physics software for photons. Different modalities are also considered and compared by the students (notably electrons and protons, considering surface doses, dose at depth and beam energies), bringing results together individually in specially prepared workbooks and then collectively as a group on the whiteboards. The students then get the opportunity for small practical experiments, as used in the earlier formats, using further peer-to-peer and expert tuition. Initial evaluations have again been very positive, and the results of further feedback are being collated and will be presented in this paper.


The experience of an independent multidisciplinary review team for different radical radiotherapy treatments at a newly established cancer centre

Robert Lally, Elaine Reilly, David Stewart, Andrew Reilly
Western Health and Social Care Trust, Derry/Londonderry, United Kingdom

It is widely accepted that incidents in radiotherapy have an adverse effect on treatment outcome and how the public perceive radiotherapy. As discussed in Towards Safer Radiotherapy, factors which contribute to radiotherapy incidents include: lack of training, competence or experience, fatigue and stress, poor design and documentation of procedures, over-reliance on automated procedures, poor communication and lack of team working, hierarchical departmental structure, staffing and skill levels, working environment and changes in process. When these factors are placed within the context of a new radiotherapy centre, there are a multitude of links in the radiotherapy chain where an incident can occur. To mitigate the risk of an incident occurring, our centre adopted an approach that each new treatment site would be reviewed by an independent team prior to implementation.

The review teams consisted of a senior physicist, senior radiographer, senior oncologist and one physicist who provided feedback to those responsible for completing tasks in the implementation plan. Reviews were conducted as a table top exercise using the Q-Pulse quality management system (QMS). Bearing in mind the factors detailed by Towards Safer Radiotherapy, the following were assessed. The multidisciplinary master training competence matrix was reviewed to ensure sufficient numbers were competent for the provision of the service; competence inferred that training had been undertaken and training records available (where applicable). To avoid undue stress, realistic follow-up times were set which took account of the fact that undue staff stress could result in an incident. All documentation was reviewed, including the clinical protocol, work instructions and records (i.e. end-to-end testing reports). Documentation reviews ensured the content was adequate and style in line with departmental templates. All results were communicated to those involved verbally and recorded via email. A final implementation review report was published in Q-Pulse where it was available to all staff. To date reviews have been carried out for prostate, breast, lung and head and neck radical radiotherapy.

For the lung implementation review, a total of n=12 findings required review by members of the lung working group. Findings ranged from the input of IRMER entitlement records into Q-Pulse, update of competence matrices and the embedding of reports surrounding end-to-end testing and the issuing of various work instructions. In total the actions were completed over 13 clinical days; less time that was required for prostate and breast.

Considering the many steps associate with radiotherapy, our centre found the implementation review process a valuable tool to identify any gaps before they could propagate to an incident. The review also provided valuable feedback to staff, which was viewed as a valuable training tool. Overall feedback was positive.
An image-guided precision proton radiation platform for preclinical in vivo research
Eric Ford, University of Washington

A decade ago new technology was developed to allow for precision image-guided x-ray irradiation of mice and rats with beams as small as 0.5 mm. This technology has allowed for numerous novel radiobiology experiments including radiation response in transgenic models of lung cancer, hypofractionated treatment regimens, stem-cell mediated effects and immune effect. Here we describe the development of a precision radiation platform for proton therapy. The device couples CT-guidance with a low-energy proton beam (50 MeV) which provides a sharp pristine Bragg peak at approximately 21 mm depth in tissue which can be collimated to sizes as small as 2 mm diameter. Monte Carlo-based treatment planning allows for the accurate calculation of dose. This platform, a first-of-kind, allows for novel radiobiology experiments exploring the effects of particle therapy beams and high linear-energy transfer (LET). This may include previously reported differential gene expression, DNA methylation and immune effects.

Improved ultrasound transducer positioning by fetal heart location estimation during Doppler based heart rate measurements
1Hamelmann P, 1Vullings R, 2Schmitt L, 2Kolen A F, 1Mischi M, 3Laar van J O E H, 1Bergmans J
1Department of Electrical Engineering, Eindhoven University of Technology, The Netherlands
2Philips Research, The Netherlands
3Máxima Medical Center, The Netherlands

Objective: Doppler ultrasound (US) is the most commonly applied method to measure the fetal heart rate (fHR) before and during labour. When the fetal heart is not properly located within the ultrasonic beam, fHR measurements often fail. As a consequence, clinical staff need to reposition the US transducer on the maternal abdomen, which can be a time consuming and tedious task. This drastically affects the clinical workflow.

Approach: In this presentation, a method is described to aid clinicians with the positioning of the US transducer to produce robust fHR measurements. A maximum likelihood estimation (MLE) algorithm is developed, which provides information on fetal heart location using the power of the Doppler signals received in the individual elements of a standard US transducer for fHR recordings. The performance of the algorithm is evaluated with simulations and in-vitro experiments performed on a dedicated beating-heart setup (see Fig. 1).

Main results: Both the experiments and the simulations show that the heart location can be accurately determined with an error of less than 7 mm within the measurement volume of the employed US transducer.

Significance: The results show that the developed algorithm can be used to provide accurate feedback on fetal heart location for improved positioning of the US transducer, which may lead to improved measurements of the fHR.

Figure 1: a) schematic of the fetal beating-heart in-vitro setup. The motor pulls a chicken heart along the z-direction with a beat-like motion pattern. By translating the US transducer through the water tank, displacement of the heart out of the US beam can be mimicked. The US transducer is controlled by an open US research system (Vantage 256, Verasonics, Inc., Kirkland, USA). b) Photograph of a chicken heart used in the experiments.
**A custom made interface that assists in the detection of autonomic dysreflexia during urodynamics investigations**

Ian Boddy, Simon Fulford, Charlotte Kemp  
South Tees Hospitals NHS Foundation Trust, Middlesbrough, United Kingdom

Patients with a spinal cord injury may be prone to Autonomic Dysreflexia (AD) in response to bladder stimulus associated with a urodynamics investigation. AD is a potentially life threatening reaction of the autonomic (involuntary) nervous system, characterized by the sudden onset of severe high blood pressure and a dramatically reduced heart rate, in addition to other symptoms such as profuse sweating, headache and nasal stuffiness.

AD can occur in patients with a spinal cord injury at, or above, the 6th thoracic vertebra (T6) [1], when the afferent nerves from the bladder are stimulated by the increasing bladder volume during the filling phase of a filling and voiding examination [2]. The localised stimulation of these nerves results in arteriolar vasoconstriction, pelvic visceral contractions and pilomotor spasms [3], which, in turn, cause an increase in blood pressure. In the uninjured patient, this sympathetic response is compensated for by vasodilatation of the splanchnic bed, under the command of the vasomotor centre in the medulla.

A patient with a spinal cord injury at T6 or above has no functioning mechanism to compensate for the increase in blood pressure because of the disruption of the long tracts involved. In these instances, careful patient management during the urodynamics clinic is essential, involving the measurement and manual recording of pulse rate (PR) and non-invasive blood pressure (NIBP) alongside the standard urodynamics data set, in order to identify the characteristic drop in PR and rise in NIBP indicative of the onset of AD.

We have developed the Urodynamics Interface (UI), a device that enables both PR and NIBP to be measured simultaneously with the standard urodynamics cystometry parameters and recorded directly in the urodynamics software. The UI allows sudden changes in PR or NIBP to be easily viewed alongside the pressure and volume traces obtained during urodynamics tests and provides the clinician with key information as to whether the patient is at immediate risk of AD, enabling them to take rapid remedial action.


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An evaluation of the effectiveness of apron used by high workload operators in a teaching hospital

D Maguire, E Seymour, J Lucey, J McCavana  
St Vincent's University Hospital, Dublin, Ireland

Although there are new International Standards for PPE, EN61331-1-2014, most hospitals still have lightweight lead-free or lead-composite aprons in use that are not certified to the new standards. In this study an assessment on the effectiveness of the aprons was carried out on the cohort of aprons in use by high workload operators in a teaching hospital.

The transmission through aprons in the inverse broad beam geometry was measured for aprons worn by operators in our CT, Interventional Radiology, Cardiology and Endoscopy departments. Aprons varied in design and manufacturer/model.

Whole-body dose measurements of staff are typically sampled at one point under the apron, the dose measured is very dependent on dosimeter positioning. For this study a more comprehensive dose survey was carried out on operators, measuring doses around the torso and down the sides of the apron using a series of calibrated TLDs or OSLs both outside and to measure its attenuation and assess distribution of
under apron dose.

A random phantom fitted with an apron had a series of TLDs placed both on the apron and through a slice in the abdomen during a simulation of a cardiology case to measure the distribution of dose through the torso.

Most of the aprons tested contained a mix of antimony and either bismuth or tungsten. The table below shows the transmission measured through the cohort of aprons available.

<table>
<thead>
<tr>
<th>Apron</th>
<th>Barrier Material</th>
<th>Transmission @ 70kV (0.25mm Pb equiv.)</th>
<th>Transmission @ 70kV (0.5mm Pb equiv.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sb &amp; Bi</td>
<td>8.2%</td>
<td>1.1% (single layer) 1.1% (overlap)</td>
</tr>
<tr>
<td>B</td>
<td>Sb &amp; W</td>
<td>9.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td>C</td>
<td>Sb &amp; Bi/Bilayer</td>
<td>6.1%</td>
<td>1.0%</td>
</tr>
<tr>
<td>D</td>
<td>Sb &amp; Bi/W</td>
<td>7.2%</td>
<td>2.1% (single layer) 1.8% (overlap)</td>
</tr>
<tr>
<td>E (backless)</td>
<td>Sb &amp; Bi/W</td>
<td></td>
<td>2.1%</td>
</tr>
<tr>
<td>F</td>
<td>Sb &amp; Bi/Bilayer</td>
<td>6.6%</td>
<td>1.1% (single layer) 1.5% (overlap)</td>
</tr>
<tr>
<td>G</td>
<td>Pb</td>
<td>5.2%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

We found that for our operators with high workloads in areas with significant exposure to radiation, some of the protective aprons they were wearing did not offer optimal protection from ionising radiation.

A cardiac interventionalist with a very high workload with an annual DAP of approximately 4,500,000 µGym² had an apron (B) with a partial front overlap that was fitted with a series of TLDs for two weeks. The annual dose for the left side was estimated to be 17mGy was measured. An apron (C) with a full overlap and a bilayer material was then given to the same operator for another two week period. With an increase in the DAP for this period, the measured doses were significantly lower, with a projected annual maximum of 4mGy to the left side.

An interventional radiologist with an annual DAP of 515,000 µGym² wearing a 0.5mm backless apron had several TLDs placed at the front of the apron as well as on a strap around the back over a 4 week period. The left posterior torso received a projected annual dose of nearly 6mGy. Dose measured anteriorly was significantly higher than calculated based on transmission measurements potentially as a result of contribution from unprotected posterior.

The aprons barrier material and its distribution are critical in the provision of adequate protection. For high workload operators aprons were replaced with an apron with a bilayer fabric with 0.5mm of lead extending from right side seam/point of three quarter overlap to left posterior oblique position of the operators back.

Collaborative design and development of a new medical device for safer, cheaper prostate biopsies

Sarah Knight¹, Sonya Sireau¹, Thomas Stone¹, Daniel Marsden¹, Vincent J Gnanapragasam¹,², Hannah Brechka², Kelly Leonard¹,², Lorraine Starling¹,², David Thurtle¹,²
¹Cambridge University Hospitals NHS Foundation Trust, Cambridge, United Kingdom. ²University of Cambridge, Cambridge, United Kingdom

Background:

The current method for diagnosing or monitoring prostate cancer is usually with a transrectal biopsy. In this procedure a needle passes through the bowel wall to reach the prostate. Inevitably, this can result in bacteria entering the urinary system and bloodstream. A significant number of men develop infections: 10% develop fevers and shivers, 1-2% will get a life-threatening infection¹,².

A safer alternative is to enter via the perineum. This results in almost no infections and is equally effective. However it traditionally requires multiple painful punctures and men need a general anaesthetic, making the procedure very costly.

A consultant urologist invented a device that replicates the safer transperineal approach but can be used with local anaesthetic. Clinical Engineering Innovation (CEI) has developed a prototype for trial and is working with an industrial partner for productisation and CE marking.
Methods:
CEI is an engineering design group within the Trust. We have applied engineering methods and experience to bring the idea from a sketch to a fully designed prototype manufactured in-house, safe and effective for use in a trial.

Our engineering design process has involved careful definition of stakeholder requirements, iterative prototyping, testing, verification and validation. Prototype devices were manufactured and sterilised in-house for rapid turnaround.

Process mapping was used to identify safety-related aspects of the design such as needle stick injuries or potential misuse. These fed into a risk assessment process and further design iterations.

Figure 1: Early prototype device partially assembled, showing its construction: a needle for local anaesthetic delivery and a sheath for the biopsy needle to access the entire prostate from only 2 puncture sites.

Results:
A prototype was used in a pilot study with 30 patients, with very promising results. There were zero episodes of infection, and all patients described the pain as tolerable. 26/30 (86.7%) men preferred the new method over the transrectal procedure; a further 3 (10.0%) would have either.

The results suggest that the new device and method is safe, feasible and preferable to transrectal biopsy for the vast majority of men – and at a cost similar to the existing outpatient procedure.

Ongoing work:
Based on the results, the project was awarded NIHR ‘i4i’ funding to develop a single-use device for volume production. CEI is working with clinicians, industrial partners and our Clinical Trial Unit to produce a device for Clinical Investigation across multiple sites beginning in January 2019, then CE marking and production by end of 2020. The project is an excellent example of successful collaboration across organisations to achieve breakthrough innovation for the benefit of patients.

References:

Commissioning and evaluation of 10MV flattening filter free beam on the Varian TrueBeam accelerator
Olivia Channon
Ipswich Hospital, Ipswich, United Kingdom. Addenbrookes Hospital, Cambridge, United Kingdom

Flattening filter free (FFF) treatments are available on the Varian TrueBeam linear accelerator and can be used to deliver a forward peaked treatment beam with an increased dose rate; a Varian 10FFF beam can...
deliver a dose rate up to 2400 MU/min compared to 600MU/min for 6MV. Increased dose rates can result in reduced treatment times, which are significant in treatments that deliver a high dose per fraction. By reducing treatment times, it is possible to reduce treatment uncertainties arising from patient motion during delivery.

The aim of this project is to implement and test the 10FFF beam model in the Eclipse treatment planning system and identify potential clinical applications for 10FFF beams such as stereotactic ablative body radiotherapy (SABR) at Hospital.

The beam model for 10FFF has been configured in the treatment planning system and it has been demonstrated that it accurately models simple square and rectangular fields, static MLC shaped fields and volumetric modulated arc therapy plans. There was excellent agreement between measured and TPS calculated profiles, depth dose curves and output factors. Dose distributions for simple and complex plans were calculated in the TPS and compared well to dose distributions measured in the Octavius phantom with 1500 array; the distributions evaluated using gamma analysis (3%/2mm). It has also been verified that the beam model can calculate the dose in the presence of inhomogeneities by point dose measurements in a Quasar phantom.

A lung SABR planning study shows that 10FFF could be implemented in treating lung SABR patients with a VMAT partial arc technique, with similar PTV coverage and OAR doses to 6MV and 6FFF plans. The average beam on time was reduced from 5.9 minutes for a 6MV plan to 1.7 minutes for a 10FFF plan, therefore significantly reducing treatment times.

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Comparing the performance of an Axial Hall Magnetometer with a 3-Axis Hall Magnetometer
Thomas McMullan
NHS Lothian, Edinburgh, United Kingdom

Introduction
Magnetic field strength around an MRI scanner can be measured using a Hall magnetometer. These devices use a Hall probe, which measures the Hall effect. A 3-axis device has been developed which simultaneously measures all three components of the magnetic field vector. The device automatically calculates and displays the resultant magnetic field strength. At our centre, the MRI staff have two Hall magnetometers for magnetic field measurements. The Lake Shore Cryotronics 410 model [2], which uses an axial probe, and the newer Metrolab THM1176 MF [3] device, which has a 3-axis probe. The Metrolab magnetometer is significantly more expensive, costing 10x the price of the Lakeshore device. Considering the large difference in cost, a comparison of the performance of each device was carried out using fringe field measurements in a region of an MR environment.

Method
A magnetic field survey was carried out along a corridor wall, which runs adjacent to the MR scanning room. Three sets of measurements were taken with each device, at three different heights measured from the floor: 0.5 m, 1.0 m, and 1.5 m. At each height, a measurement was taken at 0.5 m horizontal increments across the wall. An infrared laser was used to measure the vertical and horizontal distance for each measurement. The isocentre of the scanner was approximately 1.0 m height from the floor. Both meters were nulled using a zero Gauss chamber before commencing measurements.

Results
Figures 1, 2, and 3 show the results of the magnetic field measurements for each height as a function of the distance from the conduit. All figures show a similar trend. The largest discrepancy of 0.09 mT occurs in the 1.5 m height plot, at 0.5 m from the conduit.
Figure 1: Magnetic field strength at 0.5 m height vs distance from conduit.

Figure 2: Magnetic field strength at 1.0 m height vs distance from conduit.

Figure 3: Magnetic field strength at 1.5 m height vs distance from conduit.

Discussion
The larger errors on the LakeShore device are mainly due to angular inaccuracy when positioning the probe. In this respect, the MetroLab device is superior, and removes this source of error.

Conclusion
Both magnetometers offer similar performance in terms of these fringe field measurements, therefore considering the significant price difference between the devices, it is debatable as to whether the extra cost is worthwhile.
Comparison of beam output drift for Varian Clinacs and Truebeams: Do Truebeams require more frequent recalibration?
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\textsuperscript{1}Royal Surrey County Hospital, Guildford, United Kingdom. \textsuperscript{2}University of Surrey, Guildford, United Kingdom. \textsuperscript{3}National Physical Laboratory, Teddington, United Kingdom

Background
An recent discussion on the MEDICAL-PHYSICS-ENGINEERING JISCmail mailing list debated whether Varian Truebeams, officially released in April 2010, required more frequent calibration than the previous version of Varian Clinac linear accelerators. This prompted a closer examination of a large dataset of beam output measurements to investigate if the beam output on Truebeams drifted at a greater rate than on Varian Clinacs.

Method
A dataset containing local beam output measurements from 23 Clinacs and 27 Truebeams spanning 6 months was analysed to determine the variation in the drift of beam output for each machine. In total this consisted of 5967 measurements of 6MV beam output. The data was systematically corrected for known recalibrations. A least-squares linear regression was performed on the dataset for each machine and extrapolated to determine the annual drift in beam output. The Truebeam and Clinac datasets were then statistically compared using the Welch’s t-test. The potential impact on the number of recalibrations required was assessed.

Results
A large variation in output drift was found for each linac model and the spread of results is shown in Figure 1.

A summary of the results is given in Table 1 showing the mean drift measured for Truebeams was 1.2% greater than for Clinacs. This was found to be statistically significant (p=0.03) using the Welch’s t-test.
### Table 1: Summary of Clinac and Truebeam annual output drift measurements.

<table>
<thead>
<tr>
<th>Measured drift (%/year)</th>
<th>Linac Model</th>
<th>Difference (Truebeam – Clinac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinac</td>
<td>Truebeam</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>+0.9</td>
<td>+2.1</td>
</tr>
<tr>
<td>Median</td>
<td>+0.7</td>
<td>+2.1</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.0</td>
<td>-2.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>+5.1</td>
<td>+5.6</td>
</tr>
</tbody>
</table>

The standard deviation of the drifts was similar at 1.8-2.0%. Of the 50 linacs 39 (78%) had a positive drift.

Assuming an action level of ±2% on beam output this would result in a recalibration frequency of 26.7 months for Clinacs and 11.4 months for Truebeams. If tighter tolerances were adopted then this calibration frequency would increase.

**Conclusions**

A statistically significant difference in the rate of beam output drift was identified between Varian Truebeam and Clinacs, with Truebeams having a mean annual drift +1.2% greater than Clinacs. This supports the clinical experience expressed on the mailbase by users within a number of different centres. Varian Medical Systems attribute the rate of drift to a ‘bedding in’ period and the Truebeams were all installed more recently than the Clinacs.

Truebeams have a mean recalibration frequency which is more than double that of the Clinacs which may have an impact on required resources depending upon staff mix, dosimetry equipment and number of linacs.

### Comparison of Hyper-IMRT with VMAT for Prostate Cancer utilising Multi Criteria Optimisation

**Comparison of Hyper-IMRT with VMAT for Prostate Cancer utilising Multi Criteria Optimisation**

Steven Livingston, Garry Currie, Suzanne Currie
NHS Greater Glasgow & Clyde, Glasgow, United Kingdom

**Background**

New treatment options are available to deliver IMRT or VMAT plans, which includes flattening filter free beams and Varian’s Halycon solution. These offer similar treatment times irrespective of chosen planning technique due to either high dose rates or higher gantry speeds, or a combination of both. Speed of radiotherapy is important in the treatment of prostate cancer where internal anatomical changes influence the accuracy of dose delivery. This is growing importance with increasing use of hypo-fractionation regimes such as the 20 fraction CHIPP regime. This study address a comparison of two deliver techniques for this treatment with and without multi criteria optimization (MCO), which allows the creation of multiple plans for each objective. Internal findings have demonstrated that the calculation speed of IMRT is currently a factor of 10 less than when using VMAT.

**Methods**

Ten patients, previously treated for low and intermediate prostate cancer, were retrospectively planned using the Eclipse Treatment Planning System [Varian Medical Systems, Palo Alto, CA, USA] with a combination of RapidPlan and trade-off exploration for both hyper-IMRT (13 fields) and VMAT (2-full arcs). Two plans were created for each patient using IMRT and VMAT technique with the clinical RapidPlan model used in the Centre; variation in planner experience was removed through the use of RapidPlan. Each of these sets of plans were then optimized further with multi-criteria optimization algorithm (Trade-Off Exploration). All plans were normalised to PTV3 D99%. The effect of planning technique with and without trade off exploration in these plans was assessed by a range of dosimetric parameters for PTV coverage and doses received by the organs at risk. A two tailed student t-test analysis was also performed.
Results

All four sets of plans met the required dosimetric constraints. VMAT delivered a statistically significant improvement (P < 0.05) in OAR doses (rectum and bladder) in comparison with hyper-IMRT. When assessing the difference in hyper IMRT, once trade off exploration was applied, a reduction in doses was observed for the same OARs. VMAT and hyper-IMRT, with Trade Off Exploration, showed no statistical difference in either PTV or OAR dosimetry; however, a small mean reduction with the IMRT technique was observed. Finally, comparable plan quality was found with VMAT and IMRT, both with trade off exploration.

Discussion & Conclusion

When utilising multi criteria optimisation there is no significant difference in plan quality for either hyper-IMRT or VMAT. Trade Off Exploration calculation speed with IMRT versus VMAT is significantly faster which means that the use of this new technique can be of benefit to more patients. With improved delivery systems the same or improved time for delivery with hyper-IMRT is now available.


Digital radiography doses in the big data age: A comparison of GE Dosewatch and the local radiology information system (RIS) for dose audits and diagnostic reference level (DRL) calculation in light of International Commission on Radiological Protection (ICRP) Report 135

Nathan Dickinson, Matthew Dunn
Nottingham University Hospitals NHS Trust, Nottingham, United Kingdom


Automated dose management systems have emerged, providing complete datasets; GE Dosewatch is used locally. However, computed radiology systems still rely on transcribed paper based surveys or radiology information system (RIS) data. Qualification of RIS data use for the new analysis paradigm is therefore timely.

Methods:

All 150,438 radiographic/fluoroscopic examinations in 2017 were exported from Dosewatch; all 134,437 non-zero dose area product (DAP), adult radiographic examinations were then selected. These examinations were exported from RIS, and a preliminary analysis explored

1. How complete is RIS DAP data compared to Dosewatch?
2. How accurate are RIS DAP values compared to Dosewatch?
3. Does elementary data cleaning improve RIS DAP accuracy?
4. How does elementary data cleaning improve the accuracy of the median of the room median RIS DAP for each Dosewatch examination description?

Dosewatch and RIS entries were matched on accession number. The percentage of Dosewatch examinations with a numerical DAP value in the RIS was calculated. Dosewatch DAP was recorded in mGy.cm²; the RIS contained various DAP units, while 27% of the data had no DAP unit. To convert RIS DAP to mGy.cm² for Dosewatch comparison, three strategies were explored:

- using the raw RIS unit (giving no DAP for unit-less entries)
- for each room, applying the most common DAP unit to blank entries
- for each room, using the most common unit for all entries (assuming other units were transcription errors)

For each method, the RIS DAP percentage accuracy with respect to Dosewatch was calculated. For every Dosewatch examination description, the median of the room median DAP values was calculated for each
RIS cleaning method and for Dosewatch; again percentage agreement was calculated.

Results:
1) 87% of the Dosewatch examinations had a RIS numerical DAP
2) 54.0% of the raw RIS DAPs were within 5% of the Dosewatch value.
3) Correcting for blank RIS DAP units put 64.1% of the RIS data within 5% of the Dosewatch data. Applying the commonest DAP unit increased this to 64.4%.
4) When considering the median of the room medians for each Dosewatch examination description, 31.1% of the RIS values were within 5% of the Dosewatch values. This increased to 32.4 % when correcting for blank RIS DAP units, but dropped to 32.0% when assuming the each room’s most common RIS DAP unit.

Discussion and conclusions:
RIS accuracy was poor when compared to Dosewatch. Further analysis will consolidate Dosewatch study descriptions to fully analyse a conventional examination list, and quantify the agreement between the RIS and Dosewatch. Data will be requested from neighbouring institutions to ascertain whether our results are a local phenomenon. The large datasets also provide opportunities to examine RIS recording practice by room and institution.

References:

Fiducial Markers Visibility and Artefacts in Prostate Cancer Radiotherapy
Emily Russell1, Sarah Osman1, Karen Crowther2, Raymond King2, Suneil Jain2, Cormac McGrath3, Alan Hounsell2, Kevin Prise1, Conor McGarry2
1Centre for Cancer Research and Cell Biology, Queen’s University Belfast, Belfast, United Kingdom.
2Northern Ireland Cancer Centre, Belfast City Hospital, Belfast, United Kingdom. 3Radiological Science and Imaging, Forster Green Hospital, Belfast, United Kingdom

Purpose: To qualitatively assess the visibility and artefacts of five different types of commercially available fiducial markers in the context of prostate cancer radiotherapy imaging.

Materials and Methods: An in-house phantom was utilised with eight 3D printed (PETG filament) 4.7 x 4.7 x 4.7 cm³ hollow cubes. Each cube was filled with gelatine and 3 fiducial markers (FM) were placed with spatial distribution similar to prostate implanted FM. Five cubes had unique FM. The FM investigated were; Gold Marker (GM) CIVCO (diameter x length) 1.2 mm x 3 mm (figure1-b), GM RiverPoint 1.2 mm x 3 mm (figure1-c), Gold Anchor (GA) 0.4 mm x 20 mm (figure1-d) and GA 0.4 mm x10 mm (figure1-e), and PolyMark (PM) 1 mm x 3 mm (figure 1-f). The 8th cube also had GA 0.4 x 10 mm for consistency check. The cubes were placed at the centre of a 32 x 28.5 x 24.5 cm³ water phantom. The phantom was scanned using several imaging modalities, typically used for imaging prostate cancer patients; T2w MRI sequences, CT, CBCT, orthogonal kV-pair images and integrated imaging while delivering a 1 Gy dose with a 10 x 10 cm² field on the Varian Truebeam.

Results: All GM were visible in all imaging modalities, however, as expected, they had the most artefacts on CT and CBCT scans, figure 1, with the artefacts appearing to increase with GM diameter (size). PM had the least artefacts in all imaging modalities; they were invisible on portal images and had poor visibility on lateral kV images. The smallest diameter GA were the most difficult to identify on planar kV images at 270°.

Conclusion: The choice between different FM should depend on the adopted IGRT strategy and the use of portal dosimetry.
FLUKA Monte Carlo modelling used to correct pile-up effects in NaI and plastic scintillation detectors to determine X-ray spectra at the maze entrance of a radiation treatment room
Mohammad Qutub, Richard Hugtenburg, Ihsan Al-Affan
Swansea University, Swansea, United Kingdom.
Umm al-Qura University, MAKKAH, Saudi Arabia.
Department of Medical Physics and Clinical Engineering, Singleton Hospital, Swansea, United Kingdom

A radiation room needs to have suitable shielded walls and a maze design that protects staff working close to a linear accelerator (LINAC), as well as passers-by. Experimental measurements using NaI (Sodium Iodide) and plastic scintillation detectors have been carried out at Singleton Hospital, Swansea, UK, to determine the energy spectra at different points outside the bunker. Measurements near the maze entrance of (LINAC) spectra have challenges due to the pulsed nature of the LINAC source. Mathematical methods to account for pulse pile-up have been examined, utilising the highly periodic pulsing structure of the LINAC, differing from the effects of high-intensity radioactive sources. Monte Carlo calculations of the energy distribution of scattered photons were used with measurements to calculate the typical energy spectrum at the maze entrance. The proposed algorithm uses the Monte Carlo code FLUKA to determine a response function for both detectors and the Poisson distribution method to determine the effects of the pile-up in the spectra. The Poisson distribution depends on the number of photons per pulse (μ). The quantity μ has been obtained from the ratio between the total number of events detected at different long distances from the maze entrance. Agreement was good between the corrected spectra and measurement with the NaI and plastic scintillation detectors. This agreement indicates that Monte Carlo modelling can accurately determine the spectrum of a LINAC X-ray machine. The FLUKA Monte Carlo code has also been found to be a very useful tool to guide the design at the maze entrance and shape of the treatment room maze, including issues relating to access for patient and machine maintenance without sacrificing radiation protection.

FLUKA Monte Carlo simulations used to compare bunker maze covers with different materials at Singleton Hospital, Swansea
Mohammad Qutub, Adamu Bah, Ihsan Al-Affan, Simon Evans, Richard Hugtenburg
Swansea University, Swansea, United Kingdom.
Department of Physics, Umm Al-Qura University, Makkah, Saudi Arabia.
Department of Medical Physics and Clinical Engineering, Singleton Hospital, Swansea, United Kingdom

Linear accelerator mazes are designed to reduce the radiation risk outside of a treatment room. A linear accelerator was required to be replaced at Singleton Hospital after more than 12 years of service. The opportunity motivated the evaluation of the radiation protection at various locations, including the maze entrance and the room roof. The maze shape and dimensions required some modifications to improve access to the room and also dose reduction at the maze entrance.
The FLUKA Monte Carlo code has been used to simulate a few scenarios to optimise space, cost and radiation protection. The first scenario was to remove the concrete triangle and inner nib and to extend the maze length by about 150 cm. This would involve shaping the maze and adjusting the lintel height and the opening width between the room and the maze. The second scenario was to assess the possibility of using a few mm thickness lead to cover the existing concrete walls (Al-Affan et al 2015, 2017) after removing the triangle concrete and the inner nib. The third scenario was to use high-density concrete instead of lead. Mono-energetic photons were used to represent the main components of the X-ray spectrum up to 10 MV.

Results showed that scenarios are effective for the dose reductions of photons at the maze entrance. The scenario of extending the maze by 150 cm gave a better dose reduction by about 10% than other scenarios.

Dose reductions will be presented for various locations in the maze, as well as the energy distribution of scattered photons. Advantages of the scenarios will be discussed. Energy spectra have been bench method against measurements with NaI and plastic scintillators, where a new method of correcting for pulse pile-up has been developed in associated studies.

It is concluded that Monte Carlo simulations is very useful to aid the design of a radiotherapy room. The FLUKA Monte Carlo Code was found to be a very useful tool to guide the design and shape of the treatment room maze, including issues relating to access for patients and machine maintenance without sacrificing radiation protection. FLUKA has confirmed that lead cladding has excellent potential for modifying rooms with short mazes.

High quality stereotactic radiosurgery planning and delivery with coarse resolution (5 mm) MLC
Clare Tunstall, Sriram Padmanaban, Andrew Buckle, Peter Patmore, Frank Van den Heuvel, Claire Hobbs
Oxford University Hospitals NHS Trust, Oxford, United Kingdom

Aims
Various articles have discussed the clinical significance of fine (2.5 mm) multileaf collimators (MLC) for stereotactic radiosurgery (SRS) compared to 5 mm MLC. In this study methods of overcoming the limitations of 5 mm MLC linac based SRS were applied. Delivered plans were compared with published planning studies.

Methods
26 SRS/SRT patients with 43 brain mets (0.25 to 44.09 cc) treated in our radiotherapy centre were analysed. 1 mm margin is added to the GTV for PTV. Prescription doses were 15-24 Gy in 1#, 21-24 Gy in 3# or 25 Gy in 5#. We used Eclipse TPS (v13.7) for Varian (Palo Alto, CA) Clinac iX with millennium MLC (5 mm) and Exactrac imaging system (Brainlab, Munich DE). All plans were created either using dynamic conformal arc (DCA) or VMAT RapidArc (RA) techniques with 6 MV photons and calculated using AAA (v10) on a 1 mm dose grid. Typically using 4 arcs (3-11) and 1-3 non-coplanar couch angles. The effects of size limitation, interleaf leakage and leakage through opposing closed leaves were minimised. Techniques included: isocentre and collimator angle optimisation, out of field junction leaves (for DCA), and asymmetric jaws to define target shape for better conformity. The minimum jaw size used was 2x2 cm. The plans were evaluated using selectivity (S = PTV V100%/Body V100%), target coverage ratio (TC = PTV V100%/PTV), Paddick conformity index (PCI = S x TC), gradient index (GI = Body V50%/Body V100%) and normal brain doses. Patient specific QA was performed for all patients using Gafchromic film (EBT 3) and pinpoint chamber (PTW, Freiburg) point dose measurements in a RANDO head phantom. The cumulative measured point dose was compared with Eclipse calculated and gamma analysis for the film was performed for 1mm, 5% and 2mm, 5% criteria.

Results

<table>
<thead>
<tr>
<th>Plan Quality Metric</th>
<th>Mean ± 1SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selectivity</td>
<td>0.85 ± 0.05</td>
</tr>
<tr>
<td>Target Coverage Ratio</td>
<td>0.99 ± 0.01</td>
</tr>
<tr>
<td>Paddick Conformity Index</td>
<td>0.84 ± 0.05</td>
</tr>
<tr>
<td>Gradient Index</td>
<td>3.1 ± 0.49</td>
</tr>
</tbody>
</table>
Normal Brain $V_{12Gy}$ (Single fraction) 9.94cc 4.29cc

Table 1: Plan evaluation results

Plan evaluation results are given in table 1. Target coverage was given higher priority than selectivity and PCI was at least 0.75 for all plans. The GI was < 4 for all cases except for 2 cases, one with PTV = 0.25 cc and the other where 2 mets were adjacent. For small PTVs (diameter < 2 cm), DCA produced better GI than RA. Patient specific QA results are given in table 2.

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Mean ± 1SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point Dose difference to TPS calculated</td>
<td>-2.71% 2.06%</td>
</tr>
<tr>
<td>Film Gamma Pass (1 mm, 5%)</td>
<td>96.2% 3.3%</td>
</tr>
<tr>
<td>Film Gamma Pass (2 mm, 5%)</td>
<td>99.1% 1.4%</td>
</tr>
</tbody>
</table>

Table 2: Patient specific QA results

Conclusions

SRS/SRT planning using DCA or RA with 5 mm MLC adopting above methods can produce high quality plans comparable to published studies utilising Gamma Knife or a Linac with 2.5 mm MLC. Cases involving complex target/OAR geometry will benefit from RA. For PTVs of diameter < 2 cm DCA is preferable.

How does Eclipse model dose through a hip prosthesis?
Maryke Fox, Michael Alexander
Royal Shrewsbury Hospital, Shrewsbury, United Kingdom

An increasing number of patients presenting for prostate radiotherapy have prosthetic hips. It is well known that modern treatment planning systems are unable to accurately model dose in the vicinity of high density prostheses. This work sought to characterise how dose is modelled by the Eclipse TPS around a hip prosthesis in a water phantom by comparing the modelled dose with dose measured by a Farmer chamber and find estimate dose due to scatter. Transmission, lateral scatter and back scatter were measured at a range of distances from the prosthesis and compared to the Eclipse modelled dose. It was found that dose distal to the prosthesis was underestimated by over 20%, backscatter was not modelled at all by Eclipse but lateral scatter was adequately modelled. The dose due to backscatter and lateral scatter from the prosthesis were not significant contributors to dose. These results indicate that planners should avoid treating through prosthetic hips, and that dose due to scatter was unlikely to cause ill effects.

Identifying patients that would benefit from the use of interstitial needles during Image Guided Brachytherapy
Ceri Davies, Kate Parker, Jane Powell, Teresa Perrett
Velindre Cancer Centre, Cardiff, United Kingdom

Background:

Interstitial needles can be used for a subsection of patients in Image Guided Brachytherapy (IGBT), in addition to the intracavitary applicator, to improve tumour coverage and/or reduce dose to organs at risk (OARs) [1] [2]. At our centre patients are treated with three brachytherapy fractions using a Vienna ring and intrauterine tube applicator set. To fully optimise treatment for patients it is necessary to use needles for all fractions and a method for identifying which patients would benefit from interstitial needles is required. A study was carried out to determine whether it was possible to predict if needles would be beneficial and if so, how many needles and through which section of the intracavitary ring they should be inserted.

Method:

A total of 8 patient pre-treatment MRIs were assessed by a brachytherapy oncologist to determine whether they thought the patient would need interstitial needles. All patients had completed their IGBT treatment without interstitial needles. Of the 8 patients, it was determined 2 would not benefit from interstitial
needles. The remaining 6 were replanned using interstitial needles and demonstrated an improved HRCTV coverage. For these patients the oncologist was asked to predict which needle positions would be required.

Results and Discussion:

The oncologist’s predictions for the use of interstitial needles was found to agree with the replanning study approximately half of the time. The oncologist however only selected patients for interstitial needles based on the size and shape of the treatment volume alone. The replanning study showed some patients with relatively small HRCTV volumes also benefited from interstitial needles due to the close proximity of the OARs to the HRCTV, resulting in poor HRCTV coverage.

The results for the prediction of needle positions are shown in Table 1. From the original assessment the Oncologist would not have suggested needles for patients 1, 2 and 5 based on treatment volume alone. This corresponds to the results shown in Table 1 where for these patients the oncologist has had less success when identifying the correct needle positions. For patients 3, 4 and 6 the oncologist has predicted the needles reasonably successfully.

Table 1: Oncologist predicted interstitial needle positions and needle positions from the replanning study.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Oncologist Prediction</th>
<th>Replanning Study Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7, 8, 6? 9?</td>
<td>4, 11</td>
</tr>
<tr>
<td>2</td>
<td>4, 5 – would not have chosen needles 4, 5, 6, 8, 9 (small ring only 4-10)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8, 9, 10</td>
<td>8, 9</td>
</tr>
<tr>
<td>4</td>
<td>9, 10, 11</td>
<td>6, 7, 10, 11</td>
</tr>
<tr>
<td>5</td>
<td>10, 11</td>
<td>9, 10</td>
</tr>
<tr>
<td>6</td>
<td>5, 6</td>
<td>5, 6</td>
</tr>
</tbody>
</table>

Conclusion:

It was found that the use and position of interstitial needles for bulky tumours could be predicted relatively successfully however it was harder to identify those patients with smaller tumours that would benefit from interstitial needles due to OAR proximity.

References:


Implementation Of A New Craniospinal Irradiation (CSI) Technique

Alison Cole, Jackie Poxon, Sweta Bowles, Niall MacDougall
Barts Health NHS Trust, London, United Kingdom

Background

Craniospinal irradiation (CSI) uses matched fields to irradiate the length of the CNS. Accurate positioning of matched field edges on delivery is crucial to prevent large dose errors occurring at the junction.

Often, two spinal fields are required. These are typically matched with diverging jaws, the match point being located at the anterior edge of the target volume (patient prone). However, high doses to anterior abdominal tissues occur where the fields overlap.

A newly proposed technique\(^1\) reduces these doses, achieving a non-divergent jaw match using gantry and couch rotations. In this study, delivery accuracy for old and new techniques was assessed, along with dosimetric impact of couch shift, jaw and gantry errors.

Methods
Test plans representative of old and new CSI techniques were prepared and delivered to a MapCHECK 2 diode array (Sun Nuclear). For each technique, fields were matched at detector level, effective depth 5cm. Plans were normalised to deliver 1.5Gy at the field junction.

Machine parameters were as follows:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Field 1</th>
<th>Field 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Couch</td>
<td>Gantry</td>
</tr>
<tr>
<td>Old CSI</td>
<td>0°</td>
<td>0°</td>
</tr>
<tr>
<td>New CSI</td>
<td>0°</td>
<td>0°</td>
</tr>
</tbody>
</table>

To prevent jaw calibration differences corrupting the comparison, the same jaws were used at the junction for both techniques.

Preliminary half beam block (HBB) measurements with +/-1mm introduced jaw errors were carried out to assess the MapCHECK’s sensitivity to errors. Test plans were then delivered with exact junction matching, +/-1mm introduced jaw errors, +/-1mm longitudinal couch position errors and +/-1° gantry errors (new CSI technique only). Differences between expected and measured doses were analysed using SNC Patient software (v6.1).

Results

Dose errors were quantified according to the mean deviation of measured dose from expected dose across nine detectors at the field junction. Results are summarised below:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Mean (s.d.) Dose Deviation from Expected Dose (cGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBB exact</td>
<td>Exact match 5.0 (1.0) 1mm gap (jaw) -18.2 (5.1) 1mm gap (couch) -44.1 (1.9) 1mm overlap (jaw) - 1mm overlap (couch) +1° gantry error - 1° gantry error -</td>
</tr>
<tr>
<td>Old CSI</td>
<td>6.3 (6.2) -31.7 (9.8) -22.7 (10.3) 38.4 (9.7) 39.6 (10.2) -</td>
</tr>
<tr>
<td>New CSI</td>
<td>-8.9 (3.3) -51.5 (7.8) -53.1 (8.8) 18.2 (5.7) 22.6 (3.0) 12.2 (3.9) 39.5 (4.0)</td>
</tr>
</tbody>
</table>

HBB and old CSI measurements were systematically higher than expected, whereas new CSI measurements were systematically lower than expected, potentially due to uncertainties in couch rotation (tolerance 1mm). Mean and maximum deviations for both techniques were within acceptable limits at <6% and <10% of the prescribed dose respectively (Figure 1).
Introduced jaw and couch errors adversely affected the dose at the junction for both techniques (mean deviations ranged from 12% to 35% of the prescribed dose). Gantry errors of plus and minus 1° led to mean overdoses of 8% and 26% of the prescribed dose respectively.

**Conclusion**

Delivery of the new technique was tested and field matching was found to be acceptable, with error analysis showing no clinical difference from the current technique. The treatment is used with a moving match line to blur out any over- or under-doses. The technique has now been implemented, resulting in reduced abdominal doses.

**References**


**Modeling Patient CTDIvol using data extracted from CT Dose tracking software**

Seán Cournane¹, Eimear Brunell², Mike Rowan³

¹St Vincent's University Hospital, Dublin 4, Ireland. ²Tallaght Hospital, Dublin, Ireland. ³St James's Hospital, Dublin 8, Ireland

The practice of modulating tube current in CT to optimise patient dose and image quality has been in widespread use since its introduction in the early 2000s. The Automatic Exposure Control (AEC) technique operates by adjusting tube current output along the z-axis and through the x- and y-axes according to estimates of patient attenuation. A localizer radiograph, a 2-d x-ray image acquired in the AnteroPosterior (AP), PosteroAnterior (PA) or lateral tube positions, is typically used to estimate the subject attenuation and/or size, which then informs on the tube current modulation level for the subsequent CT scan. It has previously been established that patient miscentering during localiser radiograph acquisition, due to suboptimal positioning of the patient away from the isocentre, will result in misinterpretation of the patient size and attenuation properties and subsequently lead to poor radiation dose optimisation as well as degradation in image quality. The AEC strength setting may further significantly affect the CT output across different patient sizes.

While numerous studies have demonstrated the effect of subject miscentering and patient size on CT
output under standardised phantom conditions, the extent to which these parameters affect CT output has not been evaluated in the clinical setting. Radiation Dose tracking software packages have recently become available offering the ability to collate large quantities of imaging and radiation dose-related data across numerous imaging sites and facilitate their analyses. Accordingly, this study sought to evaluate patient data extracted from a dose tracking package to establish the relationship between patient and acquisition parameters, and the subsequent CT radiation output. Such analysis would prove useful for remote monitoring purposes, giving insight into local scanning techniques and CT protocol settings, and informing on dose optimisation methods.

Bayer Radimetrics™ was used to collate CT dose metrics and scanning parameters from a Siemens Somatom Definition AS+ over a 1-year period for high effective dose CT scans including Thorax–Abdomen–Pelvis (TAP), Abdomen and Thorax. Dose related parameters of particular interest included CTDIvol, patient water equivalent diameter (WED), CT scanner isocentre and patient positioning information. A log regression analysis was carried out, establishing the WED and a derived miscentring factor, which accounted for the effect of patient miscentring, as significant predictors of the CTDIvol model. Optimisation of model parameters was achieved by solving for those parameters which minimised the Pearson Chi-squared goodness of fit. Model R-squared regression coefficients ranged between 0.69 to 0.88 for different imaging protocols. The model allowed for the estimation of the reference CTDIvol (corresponding to the output for a 32 cm dosimetry phantom) for each imaging protocol, the strength value of the AEC setting employed and the degree to which miscentring affected CTDIvol. Accordingly, we demonstrate the potential for remote monitoring of CT output performance in addition to the evaluation of the implementation of scanning techniques by using patient data extracted from a dose tracking system. The simulation data would also prove useful as an educational tool towards improved optimisation.

Optimisation of treatment planning and delivery for breast treatments at Tayside Cancer Centre
Megara Srikaran
NHSTayside, Dundee, United Kingdom

Background
Breast cancer is one of the most common malignancies, affecting 1 in every 9 women, with a high mortality rate. Breast-conserving surgery followed by adjuvant radiotherapy to the entire breast is now one of the most common treatment options. This project was focused on the optimisation of the breast radiotherapy technique at Ninewells Hospital in Dundee.

Materials and Methods
A review of the current techniques employed in Dundee compared with alternative practices as documented in the literature and practiced in different centres highlighted a number of possibilities for optimisation; treatment planning was selected for further investigation. Both forward and inverse IMRT planning methods were analysed for a number of anonymised patients, considering the tangential fields only. A hybrid technique combining open and inverse planned fields was also considered. Results were compared with the current 3D-CRT technique. Each plan was evaluated using qualitative and quantitative methods to determine the dosimetric benefit or detriment that resulted for each patient. In addition, each method was compared in terms of plan quality, number of monitor units, quality assurance requirements, planning and treatment delivering efficiency.

Key Results
Results demonstrated that a hybrid inverse IMRT technique produced superior plans, even for complex target volumes, with shorter planning times and a reduced level of planning ability when compared with other techniques. However, this technique was not considered possible to implement as it required separation of open and segmented fields into two separate plans, increasing the plan checking time, and did not produce the straight superior edge required to match the tangential with the nodal fields. Hybrid VMAT did not improve the plan quality and required extensive patient specific quality assurance compared to the other methods.

Conclusion
The forward planned IMRT method was concluded as the favoured technique for planning breast radiotherapy at Dundee, as it produced high quality plans with improved mean Field-based planning target volume coverage and similar tumour bed coverage to the standard technique, plus a slight increase in lung
sparing. This technique resulted in lower total monitor units, with both the planning and estimated delivery times also reduced. This method also enables matching of the tangential fields with nodal fields using the current asymmetric half beam block method. Implementing a new technique should be done with maximal care. Whilst it may be time consuming to train the staff at the beginning, it results in a number of dosimetric advantage, as well as reduced planning and delivery times, improving the overall efficiency of radiotherapy treatments.

**Personal Dosimetry Using Instadose 1 In Cyprus. Does It Help Dosimetry Management And Radiation Safety Officers?**

Constantinos Zervides¹,², Panaretos Zervides²

¹University of Nicosia Medical School, Nicosia, Cyprus. ²Zervides Radiation Protection Services, Limassol, Cyprus

**Introduction:** The purpose of this research was to investigate the possible advantages or disadvantages Instadose 1 will bring to Radiation Safety Officers (RSOs) and to Administration Staff when compared to TLD dosimeters offered in Cyprus. Instadose 1 is a personal dosimeter that uses ion storage technology to record personal dose. Compared to TLD’s, Instadose 1 allows users to perform on demand dose readings by plugging the dosimeter into any internet enabled computer.

**Material and Methods:** 145 Instadose 1 dosimeters were assigned and guidance was given to the users (dentists, radiographers, radiology students) to perform on-demand measurements at least once a month. The Instadose 1 online system was used to track doses for all users, to notify individuals that received a high dose and to examine user compliance to radiation measurements. Furthermore, personal interviews of Administration Staff took place, to examine how Instadose 1 impacted administration burden.

**Results:** Instadose 1 eliminated the collection and distribution process associated with TLD dosimeters. The online reporting system minimises the need for archiving and report distribution since every user and the RSO had access to individual reports. Also, when there was a need for dosimeter re-assignment, this was handled locally in each facility. From the RSO point of view, the email notifications of high doses allowed for an immediate investigation of the consequences under which a high dose was received. This allowed for immediate corrective actions to be taken. Also, the on-demand dose reading allowed users to perform measurements before and after specific examinations. This allowed users to have immediate results on dose received due to the procedure performed. Unfortunately, in some cases user compliance was an issue. Some users did not follow the recommended guidelines of performing a measurement with some users not performing a single measurement throughout the period of investigation.

**Conclusions:** Instadose 1 can significantly reduce the time spent on dosimetry management, can significantly help RSO’s in trucking doses of high risk employees and allow them to act much faster compared to TLD’s when a high dose alert is issued. Also, Instadose 1 can be used as an educational tool, since it can be used to see if a procedure followed is optimal or not, in regards to radiation dose received. Unfortunately, because measurements are left on the individual, the major drawback of Instadose 1 is user compliance to measurement guidelines.

**The implementation of a Boltzmann solver photon algorithm (Acuros™) in a clinical environment**

Daniela Romao¹, Sriram Padmanaban¹, Edward Ilsley¹, Maria Hawkins¹,², Frank Van den Heuvel¹,²

¹Oxford University Hospitals, Oxford, United Kingdom. ²University of Oxford, Oxford, United Kingdom

**Purpose:** The validation and usefulness of Monte Carlo and/or Boltzmann solver type algorithms has already been performed by many different groups. They have been shown to be more accurate and (in some cases) more efficient than classical type A algorithms like AAA or collapsed cone. Despite this wholesale clinical adoption is still limited in many centres as the clinical benefit of such a new algorithm is unclear. In this paper we investigate a number of clinical sites and determine the clinical advantage of using Acuros™.

**Methods:** In a first instance the algorithm was commissioned using a combination of solid rectangular homogenous and heterogenous phantoms, in addition to a rando head phantom. In these phantoms small
volume ion chambers and GaF chromic film was used to determine the dosimetric validity. Subsequently, patient cases were selected in sites where differences in dose where expected on a theoretical basis, i.e. regions a with highly heterogenous anatomy or very small fields. The sites selected: (1) Breast with 3D conformal plans, (2) Spine SABR VMAT, (3) Lung SABR IMRT, (4) Head and Neck (IMRT and VMAT), specifically naso pharynx, (5) Brain metastasis conformal SRS plan. All plans were calculated using AAA (AAA-10.0.28) and Acuros (AXB-13.7.17) and compared.

Results: As expected there were little or no differences (of the order of 1%) measured in the homogenous phantoms for both AAA and Acuros. In the heterogeneous phantoms some differences between AAA and Acuros on the basis of measurements were seen (again as expected) with maximal discrepancies in AAA of 2 to 3%, this while AAA was consistently within 1%.

In the clinical cases, the table shows the comparison in terms of dose to medium ($D_m$) as well as dose to water ($D_w$).

<table>
<thead>
<tr>
<th>Site</th>
<th>Observations</th>
<th>Technique</th>
<th>$%$ Diff AXB$D_m$ to AAA</th>
<th>$%$ Diff AXB$D_w$ to AAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td>water-bone interface</td>
<td>SABR</td>
<td>$-4.16$</td>
<td>$-2.32$</td>
</tr>
<tr>
<td>H&amp;N</td>
<td>air-bone gaps</td>
<td>IMRT</td>
<td>$-0.75$</td>
<td>$-2.51$</td>
</tr>
<tr>
<td>Spine</td>
<td>lung-bone interface</td>
<td>SABR</td>
<td>$-0.48$</td>
<td>$-2.86$</td>
</tr>
<tr>
<td>Lung</td>
<td>lung-water and lung-bone interface</td>
<td>SABR</td>
<td>$-1.24$</td>
<td>$-1.28$</td>
</tr>
<tr>
<td>Brain</td>
<td>SRS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Observations</th>
<th>Technique</th>
<th>$%$ Diff AXB$D_m$ to AAA</th>
<th>$%$ Diff AXB$D_w$ to AAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td>water-bone interface</td>
<td>SABR</td>
<td>$-4.16$</td>
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</tr>
<tr>
<td>H&amp;N</td>
<td>air-bone gaps</td>
<td>IMRT</td>
<td>$-0.75$</td>
<td>$-2.51$</td>
</tr>
<tr>
<td>Spine</td>
<td>lung-bone interface</td>
<td>SABR</td>
<td>$-0.48$</td>
<td>$-2.86$</td>
</tr>
<tr>
<td>Lung</td>
<td>lung-water and lung-bone interface</td>
<td>SABR</td>
<td>$-1.24$</td>
<td>$-1.28$</td>
</tr>
<tr>
<td>Brain</td>
<td>SRS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interesting results were observed in breast conformal treatment and Spine SABR. In breast treatment the impact of ribs seemed to reduce dose to the target area, possibly reducing the intended dose to the patient (see fig 1). While in the spine SABR the dose to the spinal cord was underestimated (fig 2). This dose is the limiting factor for this type of treatment, so having the possibility to increase this could have clinical impact.

Conclusions: The impact of Acuros on treatment planning is clear on a dosimetric level. We have shown that a clinical impact exists. In a further development we will select a cohort of patients in sites of interest.
Low Dose Rate (LDR) prostate brachytherapy has been accepted as a treatment option for prostate cancer in a number of centres as it is an internationally accepted standard of care with excellent long term clinical outcomes, for patients with localized prostate cancer. Benefits include patient convenience and recovery, good quality of life outcomes and improved radiation dose localisation and conformity. The volume of the gland is a determining factor in the procedure, and is evaluated on the live interactive plans on planimetry software using trans-rectal ultrasound. The ability to delineate the prostate from surrounding tissue; namely, the contrast resolution, is vital for effective treatment planning. This study investigated what design aspects of a contrast detail phantom should be considered in an optimised clinically specific phantom used to evaluate trans-rectal ultrasound systems. Specifically, it presents the design and development of such an application specific phantom, with clinically relevant contrasts and targets.

The tissue mimicking material (TMM) used in the contrast-detail phantom was developed using formulations of IEC agar that were designed to produce relative contrast differences to background material, Table 1. These contrasts were determined to be relevant from clinical ultrasound prostate data. Spherical lesion targets ranging from 2mm – 10mm in diameter were produced from custom moulds. Arrays of the spherical targets were produced for each relative contrast value, at each target size, and were encased in a background tissue-mimicking material, 100% IEC agar. The completed test phantom had two scanning windows to accommodate the bi-plane views of the TRUS transducer, Figure 1. Images were acquired on both transducer arrays across a range of available system settings for each TRUS scanner. A semi-automated programme was used to objectively measure the contrast detectability by measuring the LSNR as a function of depth for each transducer array.

The contrast-detail phantom developed in this study was designed with clinically applicable contrasts; the targets with a lower contrast value to the surrounding material i.e. 50% using a lower concentration of metallic particles, represented the contrast in a typical patient. Other targets with a higher concentrations and closer to the 100% background concentration of IEC agar, were more challenging to the systems, representing a more difficult patient and was capable of providing contrast-detail performance as a function of depth with quantitative Lesion-Signal-to-Noise data for the TRUS evaluated.

The novel aspect of this phantom is the clinical relevance, in terms of design, and the tissue-mimicking materials used in construction. In particular, it provides targets of clinically relevant contrast, size and depth to determine a systems contrast-detail performance. The range of contrasts and targets sizes included in the design of the phantom provides a test object that is clinically relevant and also investigates the technical performance of the TRUS systems used in prostate brachytherapy. Furthermore, the housing was optimised for use with bi-plane TRUS transducers to improve both image acquisition and repeated evaluations using this phantom. This will allow for the differentiation of these systems and the selection of one that is optimum for the clinical task.
Background

Publication of the NHS England Report *Modernising Radiotherapy Services in England – developing proposals for future service models* made the assertion that within radiotherapy services there is an environment of competition which has resulted in minimal opportunities for sharing and learning between clinical teams and that there is evidence of wide variation in clinical practice and quality of treatment. A prostate-only treatment planning study was setup in order to consider the extent of these observations within the South West region.

Methods

In total 13 radiotherapy centres took part in the planning study. This involved:

- Completion of a basic survey questionnaire regarding local prostate radiotherapy practice
- Download an open-source dataset with pre-contoured structures and import into the local treatment planning system (TPS)
- Create a radiotherapy treatment plan according to local protocol
- Export data from local TPS and send to host centre
- Data was analysed in the host centre’s TPS and a report sent to all participating centres
Results

The report returned to each participating centre included the table below which displays the values obtained from each centre’s treatment plan for an array of dose-volume objectives that were extracted from the relevant CHHIP trial\(^2\).

<table>
<thead>
<tr>
<th>Objective (Gy)</th>
<th>Centre #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladder D50%</td>
<td>&lt;40.8</td>
<td>9.1</td>
<td>6.9</td>
<td>8.2</td>
<td>7.4</td>
<td>5.9</td>
<td>6.3</td>
<td>7.8</td>
<td>10.2</td>
<td>9.7</td>
<td>8.6</td>
<td>9.3</td>
<td>9.8</td>
<td>7.4</td>
</tr>
<tr>
<td>Bladder D25%</td>
<td>&lt;48.6</td>
<td>22.4</td>
<td>19.1</td>
<td>22.2</td>
<td>26.1</td>
<td>17.3</td>
<td>19.1</td>
<td>17.8</td>
<td>29.2</td>
<td>25.1</td>
<td>23.0</td>
<td>22.7</td>
<td>19.7</td>
<td>26.8</td>
</tr>
<tr>
<td>Bladder D5%</td>
<td>&lt;50.0</td>
<td>53.6</td>
<td>54.0</td>
<td>54.9</td>
<td>53.6</td>
<td>53.3</td>
<td>54.9</td>
<td>49.7</td>
<td>57.0</td>
<td>54.1</td>
<td>53.4</td>
<td>47.5</td>
<td>44.7</td>
<td>54.2</td>
</tr>
<tr>
<td>Rectum D80%</td>
<td>&lt;24.6</td>
<td>14.3</td>
<td>8.9</td>
<td>7.5</td>
<td>12.2</td>
<td>6.4</td>
<td>10.3</td>
<td>8.6</td>
<td>18.1</td>
<td>14.4</td>
<td>20.5</td>
<td>18.8</td>
<td>15.0</td>
<td>14.6</td>
</tr>
<tr>
<td>Rectum D70%</td>
<td>&lt;32.4</td>
<td>18.6</td>
<td>10.7</td>
<td>11.9</td>
<td>23.0</td>
<td>9.8</td>
<td>21.7</td>
<td>13.0</td>
<td>24.6</td>
<td>25.7</td>
<td>27.5</td>
<td>24.3</td>
<td>17.5</td>
<td>16.6</td>
</tr>
<tr>
<td>Rectum D60%</td>
<td>&lt;40.8</td>
<td>21.8</td>
<td>15.2</td>
<td>17.3</td>
<td>28.2</td>
<td>13.1</td>
<td>27.1</td>
<td>17.5</td>
<td>29.0</td>
<td>32.3</td>
<td>31.2</td>
<td>28.1</td>
<td>20.0</td>
<td>19.6</td>
</tr>
<tr>
<td>Rectum D50%</td>
<td>&lt;48.6</td>
<td>26.3</td>
<td>20.0</td>
<td>23.2</td>
<td>33.1</td>
<td>17.8</td>
<td>33.1</td>
<td>22.9</td>
<td>32.5</td>
<td>36.0</td>
<td>34.7</td>
<td>32.1</td>
<td>22.5</td>
<td>24.8</td>
</tr>
<tr>
<td>Rectum D30%</td>
<td>&lt;52.8</td>
<td>38.5</td>
<td>31.4</td>
<td>37.2</td>
<td>42.7</td>
<td>30.2</td>
<td>44.4</td>
<td>37.1</td>
<td>39.9</td>
<td>41.8</td>
<td>41.0</td>
<td>40.3</td>
<td>29.2</td>
<td>30.5</td>
</tr>
<tr>
<td>Rectum D15%</td>
<td>&lt;57.0</td>
<td>48.2</td>
<td>43.9</td>
<td>48.5</td>
<td>48.5</td>
<td>45.3</td>
<td>51.0</td>
<td>52.1</td>
<td>48.7</td>
<td>46.9</td>
<td>46.7</td>
<td>49.7</td>
<td>43.9</td>
<td>49.3</td>
</tr>
<tr>
<td>Rectum D5%</td>
<td>&lt;60.0</td>
<td>56.4</td>
<td>56.3</td>
<td>57.4</td>
<td>57.2</td>
<td>57.0</td>
<td>56.0</td>
<td>59.0</td>
<td>57.7</td>
<td>54.6</td>
<td>54.9</td>
<td>56.0</td>
<td>57.6</td>
<td>57.4</td>
</tr>
<tr>
<td>L Fm Head D50%</td>
<td>&lt;40.8</td>
<td>20.4</td>
<td>29.6</td>
<td>27.6</td>
<td>16.8</td>
<td>19.3</td>
<td>23.5</td>
<td>24.4</td>
<td>29.8</td>
<td>14.8</td>
<td>17.7</td>
<td>16.3</td>
<td>30.1</td>
<td>31.7</td>
</tr>
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<td>R Fm Head D50%</td>
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Discussion

All participating radiotherapy centres produced treatment plans that were acceptable according to the dose-volume objectives described in the CHHIP trial. However, significant differences in generated planning target volumes (PTV) and achieved dosimetric parameters were observed.

Conclusion

The data provided in this report enables radiotherapy centres in the region to compare their practice against their peers, facilitates reflection on local protocols and provides a potential source for development for those centres who may want to implement change.

Key references


2) Conventional or Hypofractionated High Dose Intensity Modulated Radiotherapy for Prostate Cancer, Final Protocol Version 5.0, 30 January 2009, ICR-CTSU/2006/10007, ISRCTN No.: ISRCTN97182923, MREC No.: 04/MRE02/10
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