2013 CONFERENCE ABSTRACTS

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Integrated access for assistive technology

Friday 25th January

A multidisciplinary, multi-agency approach to implementing a novel wheelchair mounted robot device

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Hereward College, a specialist education provider in Coventry, has successfully secured a wheelchair mounted assistive robotic device for evaluation by its student population. This and similar technologies are increasingly being sought, funded and provided outside the provision of statutory health and social services, for numerous reasons including: restrictions on availability of funding for high cost technologies and a lack of a robust evidence base. In this and other instances the mechanical and electrical integration onto a service users NHS provided chairs by a “third party” raise various practical and service based issues.

This report will identify important issues encountered during the preparation for the student trials. Focusing on two specific areas, firstly, the practical aspects of fitting and using the device and secondly the experience of collaborating with statutory health services from a third sector perspective.
Over recent years iPads and iPhones have started playing an increasing role in assistive technology. They are heavily used in alternative and augmentative communication (AAC), they are making an impact in environmental control (EC), home automation and wheelchair control systems. They can take over many of the functions of a computer, such as web browsing and emailing and offer different accessibility options for people using these features. In the market for mobile phones and tablets, the main rival to Apple devices are those using the Android operating system. Android devices are also increasingly being used for assistive technology functions and there is huge further potential. However there are currently not as many ‘apps’ for assistive technology for Android as there are for iPads and iPhones. This presentation will discuss the potential use of Android devices for assistive technology and the potential for integration of assistive technology functions into a single device using Android. Some current apps for AAC and EC will be discussed and the pros and cons of Android versus iPad for assistive technology will be explored. A case study will be presented of an iPad user from the Royal Hospital for Neuro-disability who uses the iPad for AAC, computer functions and limited environmental control. The case study will discuss why an iPad was used and an Android device was not.
The Challenges of Integrating Complex Electronic Assistive Technology - 10 year's experience in a nutshell

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The Barnsley Assistive Technology service has provided integrated eAT systems for over 10 years. This paper will provide an overview of some of the lessons learnt from provision of these often complex systems.

A brief overview of some of the commercially available options for integration of eAT will be provided. In some cases custom made devices are used to provide integration between different eAT components and an overview of these devices and their design will be provided.

Case studies are provided to illustrate some of the types of custom integrated system that we provide. The trade offs in provision of each type of system, based on our experience, will be discussed.
The high energy gamma emissions of 131I and high activity concentrations typically seen in patients who have received 131I therapy for thyroid cancer can result in spoke artefacts caused by septal penetration. These artefacts make it difficult to distinguish the physical extent of regions with high 131I uptake and can obscure regions of low uptake such as metastatic spread to nearby lymph nodes. Three methods of reducing septal penetration spoke artefacts in 131I planar imaging following thyroid cancer treatment were investigated using phantom and patient data. These methods were triple energy window (TEW) scatter correction, Richardson-Lucy deconvolution with total variance (TV) regularisation and TEW correction followed by deconvolution.

Since septal penetration artefacts are seen in scatter window data (particularly in the upper window), the use of TEW correction as a method of reducing septal penetration artefacts was investigated. Deconvolution also has the potential to improve the appearance of septal penetration artefacts, since it aims to recover an unblurred image by correcting for the known response of the system to a point source. We therefore measured a point spread function (PSF) of 131I in air for our system, and used this as an input to a Richardson-Lucy algorithm. This iterative deconvolution method uses maximum likelihood estimation adapted to Poisson statistics. To suppress noise amplification with increasing numbers of iterations, TV regularisation was used.

To investigate these techniques, planar imaging of a NEMA IEC body phantom was performed using a GE Infinia gamma camera with a 256 matrix, 450s acquisition time, 20% photopeak window width and 6% scatter window widths. Three spheres (12, 17 and 22 mm diameter) were filled with 131I, with an activity concentration of 1.4 MBq/ml and the sphere to background ratio was 3300:1 (a large ratio was necessary for good visualisation of the septal penetration artefacts). Deconvolution was performed using DeconvolutionLab, an ImageJ plug-in. Mean counts in ROIs positioned on and between the spokes were used to determine the effect of the different correction techniques and to optimise the deconvolution parameters.

The difference between spoke and background counts was found to be reduced by a factor of 2 for TEW; 3.3 for deconvolution; and 28.6 for TEW correction followed by deconvolution. These reductions in the appearance of the spokes are supported by the images shown in Figure 1. The most substantial visual improvement can be seen for the combined TEW-deconvolution method. Septal penetration artefacts are not visible in this image and the spheres are well distinguished. Similar visual improvements were also seen when applied to patient images. Future work includes the investigation of the quantative accuracy of these methods for patient images, their application in SPECT and improved patient dosimetry.
Figure 1. NEMA IEC body phantom images using (a) no correction; (b) TEW correction; (b) Richardson-Lucy deconvolution; and (d) the combined method. The same greyscale windowing was used for all images.
Implementing a new 18FDOPA PET-CT imaging service for children with Congenital Hyperinsulinism (CHI)

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Objective:
To establish a high-quality 18FDOPA PET-CT imaging service for the diagnosis of focal congenital hyperinsulinism (CHI). Previously, CHI patients were referred for imaging outside the UK.

Methods:
The service was established through the collaborative efforts of the Northern Congenital Hyperinsulinism (NORCHI) service, the Royal Manchester Children’s Hospital (RMCH), the Nuclear Medicine Centre at CMUH (NMC) and the Wolfson Molecular Imaging Centre (WMIC). Procedures for radiotracer production, patient selection and preparation, image acquisition and analysis were developed and appropriate quality assurance implemented.

Results:
27 patients have been imaged (as of 21/11/12) since April 2011, with median (range) age of 4.8 (0.1-16.1) years. All but one of the patients underwent general anaesthesia, followed by injection of 18FDOPA and PET-CT including dynamic PET and contrast CT. The median (range) yield of 18FDOPA was 109 (53-259) MBq at the time of injection, enabling children weighing up to 45 kg to be imaged. PET image reconstruction was optimised to provide clear definition of 18FDOPA uptake patterns in the pancreas for all patients. For 7/12, the scan results were corroborated by another international PET centre with greater 18FDOPA experience; histological confirmation is available for 4/12.

Conclusion:
This service represents a major innovation, providing an essential diagnostic service to patients with CHI throughout the north of the UK.
The role of 68Ga-DOTATATE and 177Lu-DOTATATE in the management of patients with neuroendocrine tumour – single centre experience

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Henry H. Tam, Amy Eccles, Abrar Gundroo, Neil Soneji, Adil Al-Nahhas

Introduction:
The end of the last millennium saw the advent of DOTA-peptides as ligands for somatostain receptors (sstr). DOTA-(Tyr3)-octreotate (DOTATATE) exhibits specificity for the sstr2 which is overexpressed in various malignancies including tumours of neuroendocrine (NET) origin. 68Ga labelled DOTATATE possesses superior imaging characteristics compared to conventional NETs imaging tracers (such as I-123 MIBG and In-111 octreotide). 177Lu, a predominant beta emitter, bounded to DOTATATE has found use in the treatment of NETs. We report our experience with 177Lu-DOTATATE therapy in patients diagnosed with NETs. The tumour response to 177Lutetium therapy was correlated with size-based RECIST criteria on anatomical imaging and degree of uptake on sstr imaging.

Methods and materials:
8 patients who underwent complete course of 4 cycles of 177Lu-DOTATATE therapy were identified retrospectively from PACS from 1/9/2008 to 30/11/2012.

All patients underwent contrast enhanced CT and sstr imaging prior to the start of 177Lu therapy. Response was assessed according to RECIST 1.1 criteria and change in tracer uptake on repeat imaging after 4 cycles of 177Lu therapy. Patients with “progressive disease” according the RECIST or an increase of tracer uptake ≥ 25% were classified as “unfavourable response”, while the other RECIST categories (“stable disease”, “partial response” and “complete response”) and/or a reduction of tracer uptake by < 25% were classified as “favourable response”.

Results:
The cohort comprised of 8 carcinoids and 1 paraganglioma. 3 patients showed partial response on RECIST with concomitant reduction in tracer uptake, 2 patients showed stable disease on RECIST but reduced tracer uptake, 3 patients showed disease progression on both RECIST and sstr imaging.

Discussion:
The present results are in keeping with previously published case series. Response to 177Lu therapy in patients with NET appears superior to conventional chemotherapeutic agents, although this needs further corroboration with a larger cohort.
Adaptive radiotherapy
Wednesday 27th February

Review of Tomotherapy Planned Adaptive for Head and Neck treatment
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The Tomotherapy Planned Adaptive module recalculates the patient’s treatment plan on a pre-treatment MVCT scan, thereby enabling the impact of anatomy changes during treatment to be assessed. Eighteen months after the clinical implementation of Tomotherapy at Nottingham, a review of the use of Planned Adaptive for Head and Neck patients has been conducted.

Over a 12 month period, from November 2011 – November 2012, a total of 119 Head and Neck patients were treated on Tomotherapy, of which 28 (24%) had an assessment of their plan with Planned Adaptive at least once during their treatment. The main reason for performing a Planned Adaptive assessment was weight loss; other reasons included to check effectiveness of bolus or the impact of removing bolus. Judgement on the need for a re-plan was made by the patients’ consultant, with PTV coverage and spinal cord dose being the primary considerations. Thus far, no patients have required a new treatment plan as a result of changes observed in the Planned Adaptive calculation. However, the process gives valuable reassurance that the treatment effectiveness and safety have not been compromised.

An evaluation of timings suggests that a replan would require approximately 2 hours of consultant time, 3 hours radiographer time, 4 hours physicist time and 1 or 6 hours technician time, depending whether a new immobilisation shell is needed. It is anticipated that it would take approximately 1 week for all stages of the process to be completed.

As part of the review process, a retrospective assessment of parotid dose will be performed. The parotids have been re-outlined on the MVCT data set and DVH data will be compared to that of the original plan. The results of this analysis will be presented at the meeting.
Adaptive Radiotherapy in Head and Neck Patients: Our Experiences at Ipswich Hospital

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Purpose/Objective
Cone beam CT (CBCT) scans in head and neck patients can be used to assess changes in dose distribution due to weight loss or set-up discrepancies. At Ipswich Hospital CBCT scans are either requested on an individual basis or acquired as part of a single centre clinical trial comparing 2D and 3D IGRT protocols. The secondary endpoint of this trial was to assess the benefit of adaptive planning in this cohort of patients. We present our results and experiences to date and demonstrate how these have informed our image guidance protocols.

Method and materials
Radical head and neck patients are treated using volumetric modulated arc therapy. All patients receive daily online image guidance using 2D orthogonal radiographs. CBCT scans are requested after observing significant changes in body contour or setup. Patients in the clinical trial received weekly CBCT scans. On each scan the CTVs were recontoured by a single clinician and the dose to 5% (D5%) and 95% (D95%) of the CTV was calculated.

Dose calculation on CBCT scans is complicated by potential Hounsfield unit inaccuracies. In this work our approach is to recalculate the original treatment plan on both the CT and CBCT scans without any heterogeneity correction. The relative effect of changes in body contour can be estimated by comparing the two dose distributions. Alternative methods of dose calculation will be presented at the meeting.

Results
3 head and neck patients referred for a CBCT have required a plan modification or a replan. Weight loss has resulted in an increase in dose to either the spinal cord or oesophagus. For 2 out of 3 of these patients these changes were detected in week 3/6 of their treatment, allowing enough time for a new planning CT scan to be performed.

8/15 patients entering the clinical trial have had their CBCT scans analysed. 3/8 patients demonstrated decreases in CTV coverage (D95%) between 5.7%-19.4% over their six-week treatment, and between 1.6-5.6% after week 3. This has occurred in the neck or shoulders where changes in body contour have moved the CTV away from the high dose region.

Conclusion
For radical head and neck patients we have observed changes in CTV coverage or organ at risk doses throughout a patient’s treatment. Some changes have been detectable in the first half of their treatment schedule. This has justified a replan using a conventional planning CT scan. This work has informed our decision to implement routine CBCT for all head and neck patients at fractions 3 and 12 of a 30 fraction radiotherapy course.
In our institution, patients receiving Helical Tomotherapy treatment undergo daily image guidance using MVCT. Subsequent application of the patient's treatment plan to an MVCT dataset allows a routine dose difference analysis (DDA) to be performed, where planned and delivered dose distributions are compared.

Routine use of a DDA on patients undergoing radiotherapy of the Head and Neck region revealed that despite the use of thermoplastic shells for patient immobilisation, subtle changes in shoulder positioning can create significant dose differences in inferior aspects of nodal PTV volumes. Measurements on a selection of past patients revealed sup-inf shoulder positional changes of up to 12mm in one extreme case.

In order to counter this effect, our planning protocol was adjusted to incorporate directional blocking structures in the shoulder regions, therefore preventing beam entry through this area. Retrospective analysis was performed to evaluate the dosimetric impact of shoulder block application by comparing plans with and without these structures. The dosimetric impact of different changes in shoulder position was also assessed and the optimum extent of the directional blocking structure was determined using these results.
Adaptive planning in response to variations in patient anatomy during IG-IMRT using CBCT in Head and Neck Cancer

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Purpose
To continue to evaluate and ensure the quality of the adaptive planning strategy used at our centre in response to set up problems and to changes in weight and tissue volume in patients with Head and Neck Cancer treated with Image Guided inverse planned IMRT.

Method
An initial study was carried out between March and December 2011, where it was ascertained that 15 adaptive interventions were required out of 110 patients planned using Elekta CMS Monaco V2.03 TPS. The current retrospective study will be updated to include patients up to December 2012.
Cone-beam CT is routinely used to assess set up and contour changes in all patients. Off-line protocols are used unless otherwise specified by the treating Clinician. A step-wise approach has been established to address planning interventions required prior to or during a course of IMRT. Step 1: recalculation of the treatment plan on the original planning CT scan (CT-1) using an external contour generated from CBCT datasets. A Clinician evaluates spinal cord (SC) dose and visually assesses target volume dosimetry. Step 2: in those cases where SC or target dosimetry do not meet constraints/objectives, a new planning CT scan (CT-2) ± new shell is performed. The original target and OAR volumes are copied, assessed and edited in CT-2. The plan from CT-1 is copied into CT-2 and recalculated using the QA module in Monaco. A full dosimetric assessment is carried out. Step 3: Where constraints/objectives are not met in step 2, a new plan is optimised on CT-2 and individual patient QA performed. Patients whose changes are identified on or prior to fraction 1 go straight into step 2.

Results
Previous results showed there were 15 adaptive interventions, 7 due primarily to weight loss, 5 to changes in volume and 3 due only to set-up issues. At intervention, median (range) fraction number was 21(0-28), median delivered dose 42Gy (0-56Gy) and median weight loss (% of original body weight) -4.8% (+3.2 to -12.1). Three cases went straight to step 2 and 2 to step 3. In 4 of these 5 cases, changes were identified prior to or at fraction 1 and one case had weight gain. Of the 10 cases where Step 1 was carried out, median (range) maximum SC dose was 41Gy (37-42), similar to that of the original plan. Nine cases were considered appropriate to continue on the original plan. In total, only 6 new IMRT plans were required.
Our current study will be analysed using the same method to see how our adaptive planning strategy has evolved.

Conclusion
The initial study showed the number of new IMRT plans required in the Head and Neck Cancer population to adapt to changes in weight/volume and set-up can be reduced by a step-wise approach that utilises CBCT data to carry out interim evaluations of OAR and target dosimetry. This avoids not only lengthy plan optimizations but also the need for additional individual patient QA thereby reducing the impact on both planning and linac resources in a busy Radiotherapy Department.

The results of the current study will be used to make processes more efficient and improve objectivity of decision making using our experience.
Dosage guided adaptive radiation therapy using Cone beam CT and Transit dosimetry
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Introduction:

Image Guided Radiation Therapy (IGRT) has provided the opportunity to more accurately match the placement of radiotherapy dose to the intended target volume within the patient, essential with highly modulated treatment modalities. It also allows monitoring and treatment plan modifications in case of anatomical changes affecting the delivery of dose to the target area. Treatment plan or dose adaptation is a needed pathway for quality clinical practice if appropriate resources are available. In our study, we integrated the Cone Beam CT [CBCT] based imaging modality with EPID based transit dosimetry process to guide dose adaptation for head & neck VMAT deliveries.

Material and Methods:

Edinburgh Cancer Centre has been practicing CBCT based IGRT since its inception in 2010 for conventional conformal treatment techniques and for Rapidarc based treatments from 2011. All the treatments and the CBCT imaging process were performed using Varian Clinac 21EX & Novalis-Tx linear accelerators. CBCT images were taken using the half-fan beam mode with bow-tie filter in position. The transit dosimetry images were taken using MV aSi 1000 EPID imager in the continuous acquisition mode on the day CBCT images were acquired. The acquired CBCT images were registered with the planning CT images through semi-automatic rigid transformation method from Mirada fusion software [Mirada Medical, Oxford, U.K.]. The fused CBCT images and the transit images were used for dose calculation, analysis and comparison in the Dosimetry Check [Math Resolutions Inc., U.S.A] software.

Results and Discussions:

Dosimetry Check software provides commonly used analysis tools like point dose comparison, isodose overlay, dose-volume histogram and advanced analytical tools like Gamma Volume histogram to consider treatment plan and/or dose adaptation. The software also provides the ability to export the measured dose matrix to re-optimize the VMAT plans during re-planning process. Our early study results clearly indicated that the integration of CBCT with transit dosimetry proved to be an efficient methodology to guide the intended treatment for its best clinical outcome. Though this methodology is very promising in improving the quality of radiation therapy treatments, the accuracy of the outcome is highly dependent on uncertainties associated with the various processes involved such as the quality of CBCT images, accuracy of fusion algorithm and differences between the planning algorithm with the transit dosimetry algorithm. A detailed study is presently ongoing to quantify the various uncertainties in the whole process.
IQ scripting in MOSAIQ facilitates safe plan-of-the-day selection for adaptive cervix irradiation
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Background
In our clinic, the plan-of-the-day (PotD) concept was successfully implemented for tissue-sparing IMRT of cervical cancer patients; full- and empty-bladder planning CT scans are acquired to model patient-specific deformation of the cervix-uterus by bladder volume, using an in-house developed non-rigid registration and motion modelling method [1-3]. For each patient, the model is used to create 2 ITVs (i.e. an empty-to-half full bladder ITV (‘empty’) and a half full-to-full bladder ITV (‘full’)). The plan library consists of 2 IMRT plans and a motion-robust 3DCRT backup plan based on the empty-to-full bladder range ITV. A daily CBCT scan is used to select between the ‘full’ and ‘empty’ bladder IMRT plan and to verify that the selected plan covers the target volume.

In our current clinical version of MOSAIQ (V2.3), the selection of a PotD from the plan library is cumbersome. The current workflow for adaptive cervix irradiation requires that all plans from the plan library are imported and put into the calendar. At the time of treatment one of these plans needs to be selected, but the two plans that are not selected that day remain available for treatment unless they are manually removed after each fraction. This can potentially lead to an accident as there is no software restriction for irradiating all 3 plans on the same day. To ensure patient safety, a team of dedicated technicians and physicists assist the treatment. Extra workload due to additional QA and post-treatment administration currently limits the inflow of patients that can be treated with adaptive cervix irradiation.

Objective
To automate the workflow in MOSAIQ to ensure that each day only the correct plan is selected and used for treatment.

Methods and materials
The IQ Scripting Engine in MOSAIQ is based on Windows Workflow Foundation 4. It allows Elekta and customers to add new functionality "on-the-fly". Scripts consist of a workflow of configurable activities and can be connected to trigger points that execute them (buttons, events, timers). We created new activities that are general and not specific to PotD (and are configurable by each hospital to fit their PotD needs). With the abovementioned activities, scripts were designed to automate the workflow of the (hospital specific) PotD treatment. To be able to execute the scripts at the appropriate moment in the treatment process, trigger points were attached to the “Treat” and “QA” buttons in MOSAIQ.

Results
PotD treatments have been simulated in a development version of MOSAIQ for different scenario’s, including resuming of incomplete treatments due to linac breakdown or patient specific reasons. We shared our script with two other hospitals and they were able to modify the script with little effort to suit their specific workflow.

Conclusions
With the IQ Scripting Engine in MOSAIQ we created a fast and safe clinical procedure for plan-of-the-day selection for adaptive cervix irradiation, which reduces the risk of incorrect radiation. A general PotD IQ script will be available in MOSAIQ 2.5 enabling the treatment of more patients with PotD protocols, resulting in a reduction of dose to organs at risk in a large patient group.

References
Evaluation of the accuracy and time savings of Atlas Based Auto-Segmentation software for adaptive Head and Neck IMRT re-planning

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Purpose/Objective
In Leeds, at least 20% of H&N IMRT treatments require some form of adaptation to their treatment plan. Of these, only 35% are fully re-optimised due to time constraints. Atlas based auto-segmentation (ABAS) of the re-plan CT (rCT) using the planning CT (pCT) as an atlas has the potential to improve efficiency in re-planning by reducing manual contouring time. The aim of this work was to 1) assess the accuracy and 2) estimate time savings of using ABAS.

Material/methods
Fifteen patients with both pCT and rCT were selected. One clinician delineated high dose (HD) and low dose (LD) CTVs, patient external, spinal cord, brainstem, larynx, parotids and oral cavity on pCT. Up to 3 clinicians on 3 occasions delineated volumes on rCT so that inter- and intra-observer variability could be measured. ABAS was used to segment volumes on rCT using the manual pCT volumes as an atlas. One clinician edited ABAS CTVs, where required, so they were "clinically acceptable". Clinicians were timed when delineating and editing CTVs to estimate time savings achievable with ABAS. Manual and ABAS volumes were compared using mean distance to agreement (MDA) and dice similarity coefficient (DSC).

Results
ABAS produced all volumes with MDA<2.3mm and DSC>0.79 and subsequent editing of ABAS CTVs reduced the difference from the original manual volumes (MDA<1.9mm and DSC>0.81). Results show inter-observer variability (MDA<2.3mm and DSC>0.72) was higher than intra-observer variability (MDA<1.6mm and DSC>0.86). The inter- and intra-observer variability of delineating CTVHD was lower than for CTVLD as CTVHD generally contains more, well-defined, boundaries, whereas, particularly the inferior aspects of CTVLD, are less well defined by anatomical boundaries. Considering both MDA and DSC suggests that ABAS contours mostly agree with manual delineations to within inter-observer variability however some editing was required. The mean(1SD) times taken by a clinician to both delineate and edit ABAS CTVs were 169min(25min) and 57min(11min) respectively.

Conclusion
Volumes for H&N patients can be auto-segmented on rCT using ABAS to within a mean accuracy of <2.3mm, editing ABAS volumes increases this accuracy to <1.9mm. Inter-observer variability in delineation was higher than intra-observer variability and ABAS volumes were mostly within inter-observer variability. This analysis did not identify small local differences in contours of clinical importance, therefore ABAS volumes required some editing before use. Editing CTV volumes produced by ABAS saves approximately 2/3rd of clinician delineation time compared to manual delineation and facilitates adaptive re-planning of head and neck IMRT.
Planning For Image Guided Dose Escalated Adaptive Bladder Radiotherapy (IDEAL) Treatment

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Objectives: Changes to the bladder volume presents major challenges during standard radiotherapy treatments. This can result in the bladder not being entirely encompassed within the standard bladder margins, despite optimal positioning. Our aim is to prevent this by producing 3 individualised IMRT plans- small, medium, and large- with anisotropic margins that will enable plan of the day selection, based on daily cone beam CT, treating the whole bladder to a dose of 52Gy while escalating the tumour dose to a maximum of 74Gy.

Method: Two sets of planning CT scans were acquired for each patient. Before scanning, the patient empties their bladder and then drinks 350mls of water. After 30minutes, the first scan is done, with the second scan done at 60minutes. The GTV and CTV for both scans were outlined by a clinician and PTV small and PTV medium were created from CTV 30min. If the difference in the bladder volume between the 2 scans was less than 50cc then CTV30 was used to grow PTV large, or if the difference was greater than 50cc then CTV60 was used to grow PTV large, giving a patient specific margin.

Three simple 5-field 6MV IMRT (small, medium, large) plans were produced, and only 4-5 segments per beam were required, because the PTV volumes are mainly elliptical. The plans were assessed on maximum and minimum PTV coverage and organs at risk dose constraints derived from published data.

Results: Preliminary results are based on 3 current clinical patients. For two out of three patients, all constraints for OARs and PTV coverage, (for the 3 plans), were met. The third patient had a significant change in bladder volume between planning and starting treatment, and had to be replanned. For this patient only the small plan met all the constraints, the medium was out on the low dose bowel, and the large was out for all bowel constraints.

Conclusion: With the use of cone beam CT, daily changes in bladder volume prior to treatment can be evaluated and the most appropriate plan chosen to cover the PTV volumes, adaptive treatment. While the initial process of planning and treatment was very involved and required a dedicated team, we hope this will be streamlined in future patients. This will create a more accurate treatment for bladders. This also allows for dose escalation whilst maintaining reduced bowel toxicity and bladder sparing.
Purpose/Objective: Prostate patients at our hospital are treated to 74Gy using a full-bladder drinking protocol, which is intended to improve seminal vesicle stability and reduce dose to bowel and bladder. Tomotherapy Planned Adaptive (TomoPA) permits dose distribution evaluation using daily MVCT imaging and is frequently used to assess the dosimetric impact of subjectively-defined incompliance with the drinking protocol. To optimise the clinical workflow, a simple, consistent method is needed to identify situations in which plan adaptation may be required.

Materials and Methods: For each of 6 prostate patients receiving Tomotherapy, selected due to poor compliance with drinking protocol, 4 MVCT scans showing large reductions in bladder volume were transferred to TomoPA. Bladder and bowel were contoured on each MVCT and the dose distribution recalculated. Compliance with PIVOTAL Trial protocol constraints was quantified. A single observer investigated various potential metrics (i.e. absolute and relative reductions in (i) bladder volume and (ii) bladder extension superior to prostate apex) to determine the optimal criteria for referral to TomoPA.

Results: 5/24 MVCT scans were rejected due to limited scan length rendering identification of relevant bladder and bowel unreliable. In the remaining 19 scans, the lower dose PIVOTAL bowel constraints (i.e. V45<158cc, V50<110cc, V55<28cc) were always met, regardless of bladder volume reduction, while higher dose constraints (i.e. V60<6cc, V65=0cc) were exceeded only twice, in the same patient. ‘Mandatory’ bladder tolerances (i.e.V65<50%, V70<30%) were exceeded in only 2/19 instances, although failure to meet ‘optimal’ constraints (V50<50%, V60<25%, V70<5%) was widespread in this cohort. The 1cm PTV margins adequately enclosed the seminal vesicles (>56.2Gy) in all cases.

No metric consistently predicted dosimetric impact, although>50% bladder volume reduction from initial planning CT appeared to coincide with sharp increases in dose for both bowel (see figure) and bladder. Bladder volume could potentially be measured for this purpose with an abdominal ultrasound probe prior to the patient entering the treatment room. Potential use of linear change in bladder extension, (ruler measurement on the MVCT image) as a predictive metric that would be easily identifiable prior to treatment and require minimal additional time, warrants further study, although the current cohort did not demonstrate a strong correlation in this regard.

Conclusions: Tomotherapy prostate plans appear robust to large bladder volume changes, with dosimetric tolerances exceeded in only a few extreme cases. A bladder volume reduction >50% suggests that dosimetric evaluation may be warranted, although confirmation on a larger cohort is required prior to clinical implementation.
3T or not 3T
Monday 11th March

Measuring Treatment Response in Breast Oncology Trials using DCE-MRI at 3T

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Purpose: Tumor heterogeneity is well recognized in breast cancer and is associated with differential responses to chemotherapy. DCE-MRI is an established biomarker for monitoring treatment response and may be exploited to measure tumor vasculature following anti-angiogenic therapies. Semi-quantitative techniques that apply kinetic curve classification are well established in breast radiology1. The shape of the signal intensity-time curve following Gadolinium bolus administration may be categorized as type I (persistently enhancing), suggestive of benign tissue; type II (plateau), with an intermediate probability for malignancy; or type III (washout), indicative of malignancy2. Typically perfusion parameters are summarized and reported over a region of interest (ROI), a highly data reductive process that discards information about tissue heterogeneity. Voxel-wise analysis of enhancement kinetics and subsequent parametric mapping has been proposed for visualizing heterogeneity of perfusion characteristics2. Methods that retain spatial information ideally require subsequent visits to be co-registered into a common image space to enable comparison. Registration algorithms have previously been reported for 3D breast DCE-MRI3. Li et al. validated registration of breast images acquired at different time points to allow for analysis of corresponding low-resolution parameter maps4. The purpose of this work is to demonstrate that by applying DCE-MRI at 3T it is feasible to acquire 3D isotropic 1mm images. This study then presents the development of registration and analysis tools which have been applied to measure voxel-wise change in response to treatment in patients randomized to antiangiogenic therapy while receiving neoadjuvant chemotherapy (NACT) as part of an ongoing breast oncology trial.

Methods: Breast cancer patients were imaged on a 3T whole body MRI scanner (MR750 GE Healthcare, Waukesha, WI) using VIBRANT (Volume Image Breast Assessment), a 3D fat-suppressed T1-W fast gradient echo sequence (FA: 10°, TE/TR/TI: 2.1/4.5/14.0ms, FOV: 350×350×150mm, matrix size: 350×350×150). Five patients to-date have completed the ongoing randomized double-blinded oncology trial (www.clinicaltrials.gov/NCT01093235). Patients received six cycles of taxane and anthracycline-based NACT with randomization to additional bevacizumab (a monoclonal antibody which inhibits vascular endothelial growth factor). Patients were scanned at four time points (visits A-D): at baseline and after completion of chemotherapy cycles one, three and six. Upon study completion patients underwent biopsy and were characterized as either partial or complete responders.

3D Registration. Image registration code was developed in C++ by extending functionality within the Insight Toolkit (www.itk.org). (Visit A) Mattes’ mutual information-based B-spline non-rigid registration was used to register each high-resolution 3D temporal phase to the pre-contrast image to correct for intra-visit motion occurring due to respiratory, cardiac and
involuntary patient movement. (Visits B-D) A rigid registration step accounted for global motion due to patient repositioning between scans and the resulting translation vector was used to initialize a non-rigid B-spline transform to align the inter-visit pre-contrast images. Subsequent temporal phases were registered to the transformed pre-contrast phase using known transform parameters established from the initial inter-visit registration step. In all cases a low-resolution B-spline mesh (35 mm spacing) was used to account for gross local distortion while reducing the potential to distort treatment effects.

Image Analysis. In-house software was developed in Matlab (version 7.14) to allow the user to import and navigate through unaligned and aligned 5-dimensional datasets (x, y, slice, phase, visit), render the selected image and compute voxel-wise enhancement characteristics. Kinetic curves were classified as type I, II or III based on their average washout slope and pixels were color-coded red, green or blue according to their probability for malignancy.

Results: Kinetic curve maps were superimposed on post-contrast images (Fig 1), allowing for voxel-wise assessment of changes in perfusion characteristics. Volume of type III tissue within a spatially registered volume of interest was plotted over the course of NACT to summarize treatment response (Fig 2). Volume of type III tissue significantly decreased in all patients and residual volume at final visit corresponded to histological findings in most cases.

Discussion: The ability to register dynamic and sequential DCE-MRI data volumetrically and to visualize raw data and parameter maps in a common image space allows spatial changes in perfusion metrics to be explored. Color-coding of kinetic curve types enables the radiologist to perform a fast, visual determination of the enhancement characteristics of the lesion. Intra-visit registration should improve voxel-to-voxel correlation between temporal phases and therefore improve accuracy of kinetic curves, whilst inter-visit registration enables heterogeneous changes in perfusion characteristics to be easily visualized across visits. A major challenge in registration of longitudinal breast DCE-MRI data is to maximally register normal tissue whilst simultaneously preventing distortion of the tumor, which will typically change shape and volume significantly during treatment. Registration should be optimized for this purpose. Development of voxel-wise analysis techniques will ideally increase the statistical sensitivity in differentiating responders and non-responders; this hypothesis will be evaluated following trial completion.

Conclusions: Dynamic and sequential 1mm isotropic DCE-MRI data were registered into a common image space to account for intra-session motion artifacts as well as patient repositioning and large deformations of the breast tissue between sessions. Assessment of spatially matched kinetic curve types and volume statistics enables quantification of response to treatment.
References:
Single-voxel proton MRS in the brain shows improved metabolite quantification at 3T in paediatric patients

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Introduction: In-vivo 1H single voxel (SV) MRS is a promising technique used in characterising brain pathology in adults and children at 1.5T. However, there are limited studies performed at 3T particularly in paediatric patients. The aim of this study was to determine whether higher field strength of 3T demonstrates an improvement in metabolite determination and quality of data acquired in paediatric patients.

Methods: SV MRS was performed on 5 paediatric patients with inherited metabolic disorders on both a 1.5T Siemens and 3T Phillips Achieva TX, using the PRESS sequence. Patients within the cohort were matched for voxel locations on both scanners. The core acquisition protocol at 1.5T comprised of a TE/TR/NSA of 30ms/1500ms/128 and at 3T 38ms/2000ms/128. All spectra passed QC criteria. Raw data was taken from the scanner and analysed with TARQUIN (Version 4.2.10), fitting to a linear combination of metabolite basis functions generated at the correct field strength and echo time [1].

Results
Comparing MRS at 3T and 1.5T demonstrated significantly (t-test, p<0.05) higher signal-to-noise ratio (SNR) with an overall increase of 76% equivalent to a 32% increase per unit acquisition time. An improved spectral resolution was shown by a significant reduction in water line width (0.078 vs. 0.053 ppm, t-test, p<0.05). Comparing mean metabolite concentrations demonstrated no significant differences between metabolite concentrations at 1.5T and 3T (Wilcoxon signed rank test). Cramer-Rao Lower Bounds (CRLBs) were significantly lower in 15 out of 27 metabolites at 3T confirming improved metabolite quantification. These included creatine (Cr), glutamate (Glu), glutamine (Gln), glycine, myo-inositol (mIns) and N-acetyl-aspartate (NAA), metabolites known to be important in brain pathology. Figure 1 shows an example case. Discussion: Whilst the use of higher field strengths theoretically has many benefits for MRS including increased spectral resolution, there are few studies that have demonstrated this within a clinical environment and none published in children to our knowledge. This study shows the improvement in metabolite profile quantification which can be achieved at a higher field strength of 3T in children with neurological disorders. The increased spectral resolution allows a better discrimination between closely overlapping metabolites for example myo-inositol and glycine. This distinction is particularly important in brain tumours since myo-inositol has been demonstrated to be a marker of good prognosis and glycine, a marker of poor prognosis [2]. Figure 2 demonstrates a case from a child with a brain tumour that was scanned pre-treatment at 1.5T and 3T. In this example the resonances are shown to be readily distinguishable only at the higher field strength.

Conclusion: This study provides a promising initial indication of improvement in short echo time proton spectroscopy at 3T compared with 1.5T in paediatric patients. Improved metabolite profile determination should lead to better tissue characterization encouraging the implementation of spectroscopy at 3T in a clinical environment.

Patient Safety at 3 T - ‘It’s not that different to 1.5 T, right?’
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Introduction
In 2012 University Hospital of North Staffordshire (UHNS) moved from a department with three 1.5T MRI scanners, to a department with one 1.5T and two 3T MRI scanners. Initially this placed a significant burden on the single 1.5T scanner, as the majority of patients with implants were scanned at this field strength. The MR Medical Physics team at UHNS have adopted a number of methods to assist with the transition to higher field strength.

Safety Management Structure
Prior to the introduction of 3T, the approach to MR safety taken at UHNS was a radiographer led experience based practice. With the introduction of 3T the physics team took the opportunity to review this and change to an evidence based physics led approach. This was achieved by bringing the department in line with the MHRA1 guidelines through the closer involvement of the MR Safety Advisor in day to day patient safety queries.

Make and Model Please!
To reduce the burden on the 1.5T scanner, the MR Safety Advisor requests that the make and model of any patient implants are provided by the referrer wherever possible so that the safety at 3T can be investigated on a case by case basis.

A database has been setup to record patient safety advice given by the MR safety Advisor. So far 107 requests for implant safety information have been recorded, of which 55% were safe or conditional up to 3T, 35% were advised to be scanned at 1.5T either for safety reasons or to minimise artefacts, and 10% were contraindicated at all field strengths.

Implant Policies
The UHNS MRI department is open from 8am-8pm 7 days a week and under current arrangements it is not possible to provide physics support at all times. To avoid unnecessarily delaying scans physics have created implant policies which radiographers can follow. Currently these cover stents, heart valves, aneurysm clips, IUDs and cardiac monitoring devices with plans to develop further policies for other implant groups.

Conclusion
Due to the greater safety risks in MR associated with 3T field strength it is essential that a robust management system is in place for MRI safety. Implant safety advice is rapidly changing as manufacturers are increasingly testing implants at higher field strengths. To ensure that the most up to date safety information is used UHNS send all patient safety queries to an MR safety Advisor. The introduction of implant policies has helped reduce delays in obtaining safety information out of hours.


2 MRIsafety.com
Superior image quality in terms of signal to noise ratio (SNR) and/or improved resolution motivates the increase in field strength from 1.5T to 3T. Whether or not this translates into a significant improvement in diagnostic accuracy in brain imaging in clinical or research settings was the subject of a systematic review.

MEDLINE, EMBASE and other sources were searched over the period 1st January 2000 to 22nd October 2010 for studies comparing diagnostic accuracy at 1.5T and 3T in human neuroimaging. 275 full papers were evaluated by the SINAPSE collaborative team. Of those, 150 were identified as being relevant and they presenting data from 4500 subjects. Only a small percentage (15%) described diagnostic accuracy. Benefits were reported in the areas of fMRI spectroscopy and automated lesion detection. Little evidence was found of improved clinical diagnosis at 3T although image quality was often described as being better.

Improvements in SNR were reported but did not meet the theoretical doubling. Artefacts were worse and more time was spent on image acquisition.

Further objective evidence is needed to guide the purchasing of MR equipment for neuroimaging for routine clinical use.
Initial Experiences of Clinical MRI at 3 T at UHNS
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Introduction: In January 2012 the University Hospital of North Staffordshire (UHNS) took receipt of one Siemens Aera 1.5 T and two Siemens Skyra 3 T systems, which after a period of user training replaced the existing Philips 1.5 T systems for all clinical work. The aim of this abstract is to highlight local successes of clinical MRI that are now routinely performed at 3 T and also issues yet to be overcome or addressed.

Paediatric Imaging: Initially, it was planned to image paediatric cases on the 1.5 T Aera MRI system due to few national and European centres currently performing routine paediatric imaging at 3 T and also due to the paucity of experience both nationally and internationally. However, after a number cases were performed at 3 T with medical physics providing support, confidence in image quality increased such that paediatric head, musculoskeletal and soft tissue cases are now routinely performed at 3 T, with total patients scanned to date shown in figure 1. Future plans include developing the national premature cooled baby protocol at 3 T moving from 1.5 T [1]. However, paediatric spines with CSF flow voids and bowel MRI are causing issues with image quality to the extent that these are still done at 1.5 T.

Neuro Imaging: Standard brain and spine protocols are routinely performed at 3 T as well as more advanced techniques. To date we have performed 15 functional MRI cases; 19 perfusion cases and 13 spectroscopy cases at 3 T as well as susceptibility weighted imaging (SWI), pre-surgical plan imaging (stealth) and CSF flow as standard protocols. However, issues arising from scanning at 3 T include enhanced CSF flow artefact in FLAIR brain and spine imaging as well as increased medullary cord T2 high signal.

Cardiac Imaging: Successful cardiac perfusion and viability studies have been carried out at 3 T, however cardiac cases are still routinely carried out at 1.5 T. Further development of arterial flow studies is required before cardiac imaging can become routine at 3 T.

Body Imaging: Most body work is now routinely carried out at 3 T. The image quality has consistently improved with radiographer experience and is excellent for body MR including liver, pancreas and pelvic imaging. Body diffusion weighted imaging is of very good quality at 3T. Challenges include increased motion sensitivity in patients who cannot breath-hold adequately and bowel movement artefacts. Future plans include optimisation of small bowel MRI at 3T. Patients with significant ascites are scanned at 1.5T due to increased artefacts.

Other Imaging routinely carried out at 3 T includes breast and musculoskeletal imaging.

Brain & Spine Imaging at 1.5T and 3T
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Introduction
Clinical applications
Brain
Structural imaging
Tissue contrast and enhancement
Resolution
Susceptibility
Vascular imaging
Physiological/quantitative imaging
DWI
DTI
BOLD fMRI
ASL perfusion
Spectroscopy
Spine
Cervical
Dorsal
Lumbosacral

Conclusions
Advantages in selected applications
eg Epilepsy, cranial nerves, MRA
DTI, fMRI, ASL
Disadvantages in others
eg Dorsal spine, skull base
Optimise protocols to field strength
Select examination types for 1.5T or 3T
Longitudinally imaging; avoid mixing 3T and 1.5T
Data: storage, management, generation and legislation
Tuesday 16th April

Managing Cone-Beam CT in a Radiotherapy Environment
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P Downes, D Johns and J Wike

At present there are large amounts of cone-beam CT (CBCT) data being generated in Velindre Cancer Centre and careful thought needs to be given to managing these data. The Royal College of Radiology recommend that oncology records be kept for 8 years after the conclusion of treatment and, in Scotland, for the lifetime of the patient and for 3 years after death. This document also notes that since PACS systems preclude preferential storage of different studies most institutions tend toward the requirement that is the longest. This does not necessarily cover CBCT data and it is not clear legally whether cone beam scans come under treatment or not.

In Velindre NHS Trust, our trust policy is to retain general health records for 8 years after treatment or death, although for children it is until their 25th birthday or 8 years after death so for a single rule to be applied this would be to keep for 33 years. There is also a Medical Physics departmental policy which states that patient records are kept indefinitely. It does not qualify what type of patient record this applies to and there is no special provision for CBCT at present.

At present, there are 4 Elekta Synergy linacs each with a X-ray Volume Imaging (XVI) unit in Velindre. Each CBCT scan generates over 300 MB of data. The scans are used clinically to accurately position a patient before treatment and deliver a small radiation dose. While these images can be reviewed in Mosaic, there are shortcomings in the review functionality of Mosaic compared to the XVI client software. There are on average 15 scans per XVI per day, which amounts to 18 GB of data generated per day. This data can quite quickly fill up the XVI client PCs which generate warnings when there is only 25% disk space free.

Figure 1 Disk space on XVI clients and backup server in Velindre

The backup solution that comes with the system whereby the data is archived to tape has some limitations in storing and retrieving data. Our solution was to purchase a server that
has 4 TB of disk space in a RAID and the data from each client is backed up to the server. If no servicing of this data was performed there would be no disk space in less than two thirds of a year.

The XVI requires all the scan data for reconstructing images but only requires the first image (one of over 600) for viewing a reconstruction so a large amount of data can be removed to save disk space. Our present policy is to retain all images of active patients for at least 6 months and to remove extra patient images that are over six months old or are marked inactive, at which point the images are deleted from the local client and the backup server. This policy is maintained by some custom software scripts that are run weekly. Figure 1 shows the available disk space on our XVI client PCs over the last 15 months. This has allowed us to maintain a large amount of current scan data while not becoming overburdened with excess amounts of unwanted data. This policy is under regular review.

References
[1] BFCR(06)4 Retention and Storage of Images and Radiological Patient Data http://www.rcr.ac.uk/docs/radiology/pdf/ITguidance_Retention_storage_images.pdf
Construction of a National Digital Mammography Image Database

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Current efforts relating to the uptake, evaluation and research into digital breast imaging with X-rays (mammography and tomosynthesis) require the large-scale collection of mammographic medical images, associated data and annotations. This demand has led us to design and implement a flexible mammographic image repository which prospectively collects images and data from multiple screening sites throughout the UK.

In the OPTIMAM project we have developed systems to identify, collect, pseudonymise and transfer the images from multiple sites to our centralised repository. The automatic selection of cases and transfer of associated data is achieved by interfacing with the NBSS database. The raw and processed images, annotations and associated data are collated in a centralised store. We have developed various tools to assist our research, evaluations and comparison of digital mammography systems. These tools include software for marking and annotating lesions and undertaking observer studies at multiple remote sites. It is possible to make the tools and software developed for this research project accessible for use outside our group. To enable this we have chosen a web-based technology and portal to implement our tools. This approach benefits from easy distribution through the internet, ability to deploy on heterogeneous operating systems and hardware without the need for administration access and quick deployment and extendibility through a centralised codebase.

To date we have collected 16,211 2D images from 1,787 individuals (The data contains 830 cancers and 40-60 cancers are added each month) and 6,750 tomosynthesis cases (from the TOMMY project). Our interactive web-based portal is being used to conduct observer studies at remote sites. The portal can also be used to make the images and tools more widely available. As the amount of data collected increases, the possibilities and scope for potential applications also increase, and there is a need to extend the accessibility and functionality of the web portal. Three such extensions are training modules, interval cancer evaluations from a central location and collection, analysis and presentation of remote QC data. Our web portal and image repository links to the existing national breast screening databases (NBSS) which contain non-image data on screening episodes, radiology and pathology. This is implemented using free and open-source technologies. All data involved is anonymised.
Image data anonymisation and storage: The perils, pitfalls and promises
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In an acute hospital setting, there is often a legitimate reason to share medical images acquired for clinical diagnosis and treatment with external organisations. This can include sharing images for academic research, clinical trials and specialised image post processing and analysis. Even though all hospitals have an Information Governance framework in place to ensure safety and patient privacy, many lack organisational structure, human resources, appropriate tools and expertise to implement the framework for a robust image de-identification and anonymisation. There are numerous tools in the market for anonymising and de-identifying DICOM medical images, both commercial and open source, offering various manual and automated methods to removing patient-related information. However many of these tools do not comply with the guidelines, standards and profiles set by DICOM and IHE.

This presentation covers some important pitfalls to avoid and some best practices to embrace in anonymising and managing DICOM image repositories intended for both research and teaching in parallel or within the PACS.
Backup - fleeing the madness of tape  
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Over the course of several years, we have moved from an array of different backup practices to a single – disk based – arrangement that backs up a wide range of different systems. Most of the more important servers traditionally have been backed up by tape, but some were not backed up at all. This paper discusses the journey taken, including: issues and limitations of the existing setup – including reliability, man power, system downtime, inconsistency of approach selecting backup software – reasons for choosing BackupPC over Amanda and Bacula are discussed data transfer options – rsync and samba, full and incremental strategies client options (with and without vendor’s consent) – optimum processor and network resource usage sometimes had to give way to manufacturer requirements, particularly with regard to CE marking as a medical device issues with very large volumes – volumes that are too large can take too long, as well as utilising too much network, processor and disk i/o resource, and therefore needed to be broken down into smaller jobs or scheduled very carefully issues with locked files – some critical files have a locked status, such as database files, meaning they cannot be backed up whilst in use, and conversely cannot be used whilst being backed up in-flight and at-rest encryption – where possible, we made the decision to encrypt all backup data. Different methods to make this possible are discussed. business continuity and disaster recovery – advantages and limitations of the system to fulfil these functions is discussed. 
Hardware, virtualisation and storage devices will also be touched on.
Managing and Analysing Radiotherapy Data in the West of Scotland

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Colin McGeechan, Carol MacDonald, and Garry Currie

The Beatson in Glasgow is the UK’s busiest cancer centre and one of the largest in Europe. Some 7,000 patients are treated each year. Oncology Information Systems have been in use from 1996. The current version is Aria 10. The OIS database now holds around 80,000 patients who have been given radiotherapy treatments. At first, this system was simply a record and verify system. Later, an integrated treatment planning system was added. Subsequently, the system included scheduling for all radiotherapy related activities. At the same time, an interface to the hospital PAS was added to import patient demographics. Treatment complexity has increased steadily and increasing use is made of imaging for both planning and treatment management. Current projects include extending VMAT techniques for most radical treatments, increased used of 4D methods, clinical assessment data collection, and cancer management and review using Aria.

Data storage over this time has grown exponentially. Initially only basic demographics and treatment information was part of the patient record. To this was added, over time, 2D simulator and portal images, 2D treatment plans, 3D CT image sets, 3D treatment plans, radiotherapy scheduling information, day case chemotherapy scheduling, 3D MR and PET image sets, 4D CT image sets, and 4D treatment plans. The database is currently over 150GB and around 5TB of images are stored on servers and SANs. A larger database results in slower performance so there is a plan to examine data archiving options later this year.

Data analysis has grown from examination of yearly and monthly totals by treatment machine, through analysis by diagnosis and tumour sites, pathway efficacy, regional variations in disease presentation, and transport issues. Today we produce a wide range of scheduled reports and offer a service of data analysis and reporting to the cancer centre as a whole and to key partners in regional and national organisations.
Virtualising MOSAIQ

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The Radiotherapy department at NUH has recently switched to the Elekta MOSAIQ Oncology Information system, having previously used Nucletron VISIR. Support and infrastructure for the new system was provided by the Trust’s ICT department, who opted to virtualise in order to provide increased resilience and disaster recover capability, and to fit in with existing infrastructure thereby offering added flexibility. Challenges faced included fitting the physical specification for hardware into a VM environment, dealing with hesitance from Elekta and building a working relationship between Radiotherapy and ICT services.

Performance was optimised by dedicating storage infrastructure to serve specific components of the solution and separating IO streams within VMware, as well as adhering to Microsoft SQL server best practice. Benchmarking tests performed by Elekta before the system went live demonstrated the system was able to operate at least as well as, and sometimes faster than, a physical server environment. By utilising the skills and experience within the ICT department, the radiotherapy staff were able to focus on the clinical implementation of the system.

This work has highlighted the challenges for both provider and customer in scoping large IT project, given the many different technology platforms and hypervisors available. Collaboration between Radiotherapy and ICT enabled an effective solution to be delivered in a timely and cost effective manner.
The challenge of generating DICOM RT data from TomoTherapy archives for the VoxTox study

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Marina Romanchikova, Neil Burnet, Karl Harrison, Andrew Hoole, Andy Parker, Simon Thomas

VoxTox (Linking radiation dose at the voxel level with toxicity) clinical study aims to collect and archive clinical toxicity and optimised imaging data to improve quality of patient treatment. The trial will include over 2000 patients with prostate, head and neck and central nervous system cancers treated on two Hi-Art TomoTherapy units at Addenbrooke's Hospital between 2007 and 2017.

The anonymized clinical data is being transferred to Cambridge University High Energy Physics (HEP) Laboratories for further processing. The data consists of imaging, treatment planning and toxicity information. All imaging and treatment planning data is stored in DICOM format. Expected average data volume is 0.7 GB per patient; total data volume to be transferred to HEP will reach up to 2 TB.

Data Management
Patient data acquired during treatment must be extracted without interfering with the clinical workflow. However, to date TomoTherapy manufacturer does not provide an interface to request DICOM data. DICOM exports from TomoTherapy systems can only be performed manually, blocking Treatment Planning workstation and interrupting normal radiotherapy processes. Therefore it is essential to create a set of software tools to convert archived TomoTherapy data from proprietary data format into DICOM Radiotherapy format. Such tools are currently being developed at Addenbrooke's.

Further challenges to be faced include frequent changes of clinical data formats by TomoTherapy manufacturer, correct interpretation of archived data and setting up a concise and scalable system for data anonymization and storage.

The extracted DICOM data is anonymized and transferred via SSL connection to HEP for storage and analysis.

Expected Benefits
Linking radiation induced dose with observed toxicity will result in deeper understanding of factors determining treatment outcome and establishment of more reliable dose-response models. Patient data can be used to produce versatile phantoms for treatment planning systems both for commercial and research purposes. Furthermore, software tools developed during the study can be utilized to extract TomoTherapy data for research purposes without interfering with the treatment workflow. The results of the study may drive the radiotherapy equipment manufacturers to implement facilities for DICOM data extraction as a standard component of their software packages.
The "Epidemiological study to quantify risks for paediatric computerized tomography and to optimise doses" (EPI-CT) has been set up to investigate the relationship between the exposure to ionizing radiation from CT scans in childhood and adolescence and possibly attributable late health effects. Eighteen centres from Belgium, Denmark, Germany, Finland, France, Luxembourg, the Netherlands, Norway, Spain, Sweden and the United Kingdom are cooperating in this project, which aims to enrol approximately one million patients over the 5-year duration of the study (http://www.epi-ct.iarc.fr/). Discussed here will be aspects of the work carried out as part of the Norwegian contribution to this project.

Data on CT examinations are extracted from existing hospital electronic records held in PACS or RIS and are used to estimate the radiation dose received by each patient. This information will be matched with records from the Cancer Registry of Norway for statistical analysis. The Norwegian cohort currently comprises more than 30 000 children, and is expected to include more by completion of the project.

We will describe the approach in Norway to extracting information on paediatric CT examinations from hospital PACS and RIS and our experiences so far; protection of patient confidentiality by pseudonymisation of data; preparation of data for analysis; and ensuring that hospital information systems are not compromised by the data extraction process.

RIS records are retrieved using standard RIS queries. PACS examinations are retrieved using PerMOS software (Centre Henri Tudor, Luxembourg) which functions as a node on a PACS network and queries the PACS using standard DICOM Query/Retrieve. Installation of PerMOS has been technically straightforward but requires cooperation of local staff; its use requires some planning, since constant retrieval of CT examinations has the potential to overload some PACS networks. Retrieval therefore takes places only at specified times of the day, with a delay of several minutes between each examination retrieval. This retrieval strategy has been running in Norway for several months and has so far caused no problems to local PACS.

Following retrieval, each examination has its patient-identifying data removed and replaced with a pseudonym. Patient-identifying data and pseudonym only are sent to Cancer Registry of Norway for investigation of clinical histories; CT examination metadata with pseudonym are sent via the Norwegian Radiation Protection Authority to a central database for calculation of radiation doses. Calculated radiation doses are matched with clinical histories by their pseudonyms, then anonymised and made available for statistical analysis, along with data from the other countries participating in the project, by the central EPI-CT study team.
POSTER: Use of a Simple Virtual Computer to Maintain Physiological Measurement Software

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Helena C. Wilding and Jon J. Whybrow

Background and purpose
Physiological measurements software used within our department falls outside the remit of central IT. Often this software will typically be used on a single computer. One such system is Polygram Net Version 4.01 (Diagmed Healthcare, originally supplied by Synectics Medical), used at the RD&E for holding the results of investigations using Bravo wireless intra-oesophageal probes. This software was first acquired in 2004 to run under Windows NT and shown to work under Windows 2000, neither of which are available. It uses IIS 5.0 and .NET framework version 1.1. Experimentation has shown that it will not run on a modern trust standard Windows XP machine (we have not investigated Windows 7). This has led to the unsatisfactory situation of our having to run legacy software and hardware for this system.

Virtualisation has provided a solution. Using VirtualBox Version 4.2.6, a virtual Windows 2000 computer has been created on a modern trust Windows XP machine (Pentium Dual-Core CPU, 2.7GHz). Shared resources has allowed the Windows 2000 machine access to the trust network and the virtual machine has a larger memory resource than the original specification (Pentium III, 733MHz).

Method and results
VirtualBox Version 4.2.6 was downloaded and installed under the terms of the General Public License Version 2 onto a host Windows XP computer. Using VirtualBox a virtual computer was created, taking into account the minimum computer specifications of the software to be used. The Windows 2000 operating system was installed on the guest virtual computer with CD pass-through and serial port enabled necessary for the Bravo download. In order to test the operation of the serial port, an oximeter was used to provide a data source and a simple script was run on the virtual computer to read and report its data.

Following installation of the necessary supporting service pack and software, Polygram Net was installed on the virtual computer and, finally, the patient database attached using the shared drive feature of VirtualBox. The virtual computer was set to be operated by all users of the host operating system. The folder created on the host machine containing the virtual machine was saved to the departmental server. As a test, VirtualBox was installed on a second host computer and the virtual computer was loaded from its location on the server with its settings and software intact. Comparison of the time involved in loading studies and navigating the software showed a significant reduction when using the virtual computer as opposed to the original Pentium III computer it replaced.

Conclusions
The ability to run legacy software within the restraints of hospital IT systems can provide benefits for physiological measurement departments. Continual use of Polygram Net Version 4.01 has the advantage of cost benefit, database transparency (as the database structure is not directly compatible with newer versions) and the obvious physical space-saving benefit. The ability to save the virtual computer to a server location provides an additional robustness of the system in the advent of a fault with the local virtual computer.
Experiences of Decommissioning and Gaining Revocation of EPR permits
Miss Catrin Abercrombie, Portsmouth Hospitals NHS Trust, Queen Alexandra Hospital, Portsmouth, PO6 3LY  email: catrin.abercrombie@porthosp.nhs.uk

In July 2009, Portsmouth Hospitals NHS Trust relocated the majority of its services to the redeveloped Queen Alexandra Hospital in Cosham. This brought three sites into one, with the centralisation of nuclear medicine and radiotherapy services, and hence the need to revoke permits held for use and disposal of radioactive substances at the vacated premises.

This presentation will describe the steps taken, challenges and experiences of the Trust to prepare the evidence to submit to the Environment Agency, proving that there was no radioactive legacy left at the sites and obtain the all important revocation certificate. Every site will have its own requirements but the overall process followed in line with guidance, along with good communication with the local inspector, should provide the required outcome.

The site discussed here, St Mary's hospital, has an interesting and varied history since opening on the site of a workhouse in 1930. There have been variable uses of radioactive materials as technology and treatments have developed over the years, but it can be the items not under the remit of the most recent permits that can provide the most need for discussion.
Overview of BAT (Best Available Techniques)
Ms Kate Griffith, RSR Technical Specialist, Environment Agency, Trentside, Nottingham, NG2 5BR   email: kate.griffith@environment-agency.gov.uk

In England and Wales, Schedule 23 of the Environmental Permitting Regulations implements the Basic Safety Standards Directive, requiring the Environment Agency to ensure that:

“All exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, economic and social factors being taken into account (ALARA)."

In order to achieve this management of the generation and disposal of radioactive waste must be optimised. Best Available Techniques (BAT) are the means an operator uses in the operation of a facility to deliver this optimised outcome and so reduce the exposure to ALARA. Techniques include both the technology used and the way in which the installation is designed, built, maintained, operated and dismantled. Further information can be found in the Environment Agency’s document “RSR: Principles of optimisation in the management and disposal of radioactive waste”.

Statutory guidance from the government requires that the Environment Agency ensures that operators use BAT to:

Prevent the creation of unnecessary wastes  
Minimise waste generation (activity and volume)  
Minimise the radiological impact on people and the environment

This is reflected in the permit conditions where operators are generating radioactive waste. BAT should be used to minimise both the holdings of radioactive material, and the quantity and volume of radioactive waste. Waste accumulation should be for the minimum time period practicable and the risk of contamination minimised. The Agency’s “how to comply documents” give guidance on these more practical aspects of BAT.

Applicants for new permits that include the accumulation and disposal of radioactive waste have to submit an assessment of how the ‘best available techniques’ will be used to minimise the radioactive waste. Applications for variations that impact on the management and disposal of radioactive waste will also have to submit an assessment. Guidance is provided with the application forms.
This talk gives a summary of the principles for assessing doses as outlined in the Environment Agency's document Principles for the Assessment of Prospective Public Doses arising from the Authorised Discharges of Radioactive Waste to the Environment. The stages in any assessment are talked through and possible exposure pathways from the discharge of radioactive waste and the key aspects of models used for atmospheric and aquatic dispersion modelling are identified. Carrying out an assessment using the Environment Agency's Initial Assessment Methodology and the impact of changing the most significant parameters are discussed.
The accidental RWA: What should I do with my NAIR waste at 11pm on a Friday night?

Mr Mark Knight, Medical Physics Department, Maidstone and Tunbridge Wells NHS Trust, Maidstone Hospital, Maidstone, ME16 9QQ email: markknight@nhs.net

The National Arrangements for Incidents involving Radioactivity (NAIR) scheme can call on medical physicists to advise police on hazard mitigation for orphan radioactive sources and unknown items which are suspected to be radioactive. Under the NAIR scheme, respondents are not obliged to take custody of sources. However, they are often best placed to do so, having access to monitoring equipment and appropriate storage facilities.

NAIR respondents need to consider a number of issues, such as permitting, transport, radiological hazard and disposal of any sources taken into their custody.
RWAs – Why, When, How?
Prof Peter Marsden, RPA 2000, UCL Hospitals NHS Foundation Trust, Medical Physics, London, NW1 2BU   email: peter.marsden@uclh.nhs.uk

Following on from Dr Englefield’s presentation, this paper describes the process developed by RPA2000 for assessment of applications for RWA certificates. Following a brief resume of the RPA2000 processes I will focus on our interpretation of the EAs syllabus and how we ask applicants to submit evidence of knowledge and competence. In particular I will highlight sub-topics which may present challenges to IPEM members wishing to assemble their first RWA portfolio.
Security of radioactive materials – an update
Mrs Tanya Montgomery, Technical Specialist, Radioactive Substances Regulation, Environment Agency, Trentside offices, Nottingham, NG2 5FA
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The regulation of security for radioactive sealed sources was introduced in 2005 and is now well established. A key aspect of the success of the security regime in the UK is the joint working between the Environment Agency as the security regulator and the Counter Terrorism Security Advisers (CTSAs) as the security specialists. The guidance document “Security Requirements for Radioactive Sources” is now on its third edition and there are several key changes in the 2011 version which will be highlighted. All three versions are still in force, with the source holder’s permit defining the version which applies in each case. The EA and CTSAs are conducting a review of security at irradiator sites at the present time and this work will be summarised. A number of common issues which arise during the regulation of security will be discussed, with particular emphasis on practical issues which arise at hospital premises. The application of security considerations to unsealed radioactive material will also be briefly considered.
Can a robotic floor cleaner reduce radioactive waste from the Oncology Ward?

Mr Darren Morgan, Radiation Physics, Oxford University Hospitals NHS Trust, Old Road, Oxford, OX3 7NR  email: darren.morgan@ouh.nhs.uk
Darren Morgan, Katharine Kenny, Paul Clarke, Aida Hallam, Therese Crawley

The work presented is initial work to test the suitability of the iRobot Scooba 230 at removing radioactive contamination from floors following radionuclide therapies at the Oxford University Hospitals NHS Trust (OUH).

A number of radiopharmaceuticals are used in the oncology ward at the OUH including I-131 NaI, Y-90 Dotatate, Lu-177 Dotatate, I-131 MIBG and Y-90 SIRSpheres. The use of an automated decontamination machine was investigated as a convenient, and relatively cheap, way of reducing the time taken, and waste generated, while decontaminating patient rooms.

The effectiveness of the robot has been tested on “hot spots” of Tc-99m eluate, and also with I-123 NaI (used as a substitute for I-131 NaI). The results show that the robot is very effective at cleaning small areas quickly. A cleaning cycle lasting 5 minutes on an area of approximately 1m² removed 80-90% of both wet and dry contamination. Further cleaning over a total period of 15 minutes reduced the contamination to less than 4% of the initial level without significant spread of contamination.

This initial work confirms the data published by Westcott et al. (Operational Radiation Safety, Vol 102, No. 2) using an older Scooba 5800 series robot, is also applicable to the newer, smaller, and cheaper version. Further work aims to test the effectiveness of removing different therapy radiopharmaceuticals, from different flooring materials, and using different cleaning agents. It is expected that the use of this robot will reduce the waste produced, and the time spent decontaminating patient rooms, by providing effective automated decontamination of the floors of the oncology ward at the OUH.
EPR legislation requires an operator to use measures and techniques to achieve an optimised outcome; this process is defined as ‘Best Available Technique’ (BAT). At UHCW solid radioactive waste items, generally clinical sacks or sharps containers, are dealt with by multiple operators in a number of locations. We have developed a bar-coding system utilizing hand held data loggers to track the waste items through the approved pathway to disposal. The aim of this system is to provide a BAT process that minimises input errors associated with previous paper records, facilitates appropriate disposal and assists the auditing of data.

Individual items are entered into the system and assigned a unique five-digit barcode number. Information relating to the operator, isotope(s), activity, location, date and time is recorded as the items enter the system and are subsequently transferred between storage locations. Data is entered predominantly by scanning barcodes (e.g. item, location) or selecting from a drop down list (e.g. isotope); freehand data entry (e.g. operator ID) is kept to a minimum. At regular intervals the data is downloaded to a PC workstation. An Excel spreadsheet, utilizing macros, is used to load, sort and analyse the data.

This system allows the activity, location and length of time individual items are stored to be constantly monitored; total activities of radioisotope waste are also available. Access to this data ensures compliance with the EPR waste permit. The presentation will demonstrate the waste management system with reference to BAT.
Practicalities of monitoring radioiodine in the environment following patient treatments

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Radionuclides are used in the diagnosis and treatment of certain diseases. When administered systemically a proportion of the radionuclide will be excreted in the patient’s urine and or faeces and hence discharged into the sewage system.

Hospitals carrying out such studies and treatments are required to apply to the Environment Agency (EA) under the Environmental Permitting Regulations 2010 for a permit to cover all radioactive discharges. The application must provide a reasonable estimate of how much radioactive material is likely to be discharged and an assessment of the impact that this may have on the environment and critical groups.

For the past decade permits granted to the The Royal Marsden in Sutton have been conditional on the Trust regularly taking samples from a local brook to determine the radioiodine concentration (Bq.L-1) present throughout the year.

This presentation will describe the processes involved in deciding where, when and how to collect the required samples; how the samples were prepared and analysed; the resulting measured concentration compared against the known excreted activity. Alternative methods of sampling and analysis will also be considered.
Scheduled Maintenance
Thursday 16th May

‘Value’-based optimisation Strategies for Scheduled Maintenance
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The challenge of maintaining medical devices involves understanding how various maintenance tasks should compete for resources. Similarly throughout the NHS and healthcare systems abroad, there is increasing pressure to do as much as possible with limited money and manpower. Our colleagues outside the device-management world have begun to see ‘Value-frameworks’ as a crucial mechanism, for aligning competition for resources, with the interests of the patient and the healthcare system as a whole [Porter, 2010]. This presentation will examine what the Value movement has to offer, in the development of maintenance strategies.

‘Value’ is a hypothetical quantity representing the desirability of various situational attributes, usually in reference to outcomes of a particular decision. It might be defined to include dimensions of risk, cost and benefit and a plethora of sub-dimensions. It is “a function of their relative importance” and emphasises how they trade off. Often the purpose of EBM (evidence-based maintenance) activities is to justify more efficient and cost-effective decisions, on the basis that they will not increase risk to the patient. In contrast, the Value approach to EBM frames resource allocation as an optimisation, and might include a more holistic treatment of maintenance outcomes, including some indication of impact on clinical capacity.

This presentation will outline the ‘Value’ approach, explore its in Medical Equipment maintenance, and compare it with existing maintenance strategies, including ‘mission-criticality’, and risk-based approaches. The frameworks and findings presented here, have come about from a collaborative research effort, between Guy's & St Thomas' NHS Foundation Trust, and the Engineering Design Centre, Cambridge University.

Selected references
M.E. Porter. What is value in health care? New England Journal of Medicine, 2010b
When we (Clinical Engineers) go looking for evidence, it is often with the aim of demonstrating what we think we know from experience: that our maintenance strategy does not introduce potential harm to the patient – i.e. ‘first, do no harm…’ It seems logical, that one place we might look for this evidence, is in our records of harm to patients, from medical-device-related incidents. A study carried out in GSTFT (Guy’s and St. Thomas’s Foundation Trust) examined the potential and shortcomings of this approach. Incident data was used to answer a particular question: when can we reasonably employ ‘maintain on sight’ strategies?

At GSTFT a set of 100 medical device categories is used to assist in device management. These categories are distinguished by a mixture of device features, including principle-of-operation and area-of-application (e.g. ICU Ventilators versus PAP Ventilators), but have been chosen so that the devices within a category have similar maintenance-related risks. It was proposed that some of the low-maintenance-risk categories could be ‘maintained on sight’ – that is: without the type of scheduled maintenance that is performed by a technician.

Over 2000 medical-device-related incidents and near misses, covering a 7-year period, were filtered (according to their coding) and analysed. Using data on both actual harm and risk assessed ‘severity’, a measure of maintenance-related risk was estimated for each category. While the findings from this work have been illuminating, the most interesting outcome has been the evaluation of the data itself; its stationarity and its integrity. This analysis and the questions raised by it, have already supported further research into the integration of various data sources, to give a richer, more reliable analysis.
Risk and evidence based maintenance planning under the spotlight: can it be done legally?

In this session, we will look at the duties placed upon healthcare organisations set out under Health and Safety Legislation, including the Management of Health and Safety at Work Regulations 1999, the Provision and Use of Work Equipment Regulations 1998 and the Lifting Operations and Lifting Equipment Regulations 1998. In particular we will consider:

Overarching duty;
Hazard Identification and assessment;
Balancing risk and resources;
Consequences when things go wrong;
Example case.
In 2009 my team and I were faced with a challenge. How to balance the priorities of the equipment management service, and continue to improve it in a shrinking economy? The only option was to “think different”. We needed to develop an approach to the redesigning the service, which was evidence based, patient centred and could deliver quality improvements. In this paper we will set out the methodology we adopted and tell the story of how we got on in the years from 2010 – 2012.
Ten Years On: What Lessons have we learnt in adopting a Risk Strategy for Medical Equipment Maintenance and What Next?
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Chris Hacking & Phill Ward: Clinical Engineering, United Lincolnshire Hospitals NHS Trust (ULHT)

Ten years ago, with agreement with the trust senior management, Clinical Engineering adopted a risk strategy for medical equipment maintenance based on the ‘immediacy of the patient outcome’. The aim was to re-engineer the service to balance demand with capacity.

Lessons Learnt:

We review the philosophy and monitoring method of our approach and reflect on its impact on quality and patient safety.

Some key pointers:
Risk Score
Service Protocols
What don’t we do?
Targets
Davis Balistracci ‘plot the dots’ approach applied to medical equipment maintenance
Perception of Clinical Engineering as Problem Solvers
It isn’t just maintenance – it’s the whole life management of medical equipment

What Next?
All Clinical Engineering departments have rising demands on their maintenance schedules, not only because of increasing numbers of equipment but also increasing complexity of each device. We feel we’ve pared down the servicing to a level that we’re happy with but don’t feel we can reduce it further. If we do reduce it further then quality and patient safety will be compromised.

In addition to changes in numbers and complexity of the technology we’re constantly being asking about workforce planning, normally with the underlying objective of reducing grades of staff required to undertake a particular role. BUT:-

Within the changing landscape of Clinical Engineering we have to consider other key elements that include:

Equipment connected to our network, patient demographics / links to PAS
Equipment that requires software to maintain.
Clinical Information systems pulling data from medical equipment

In this presentation we will present some emerging ideas that adds a simple complexity element to each device to see how that impacts on the changing skill set required within our team.
Planned Maintenance from the perspective of NHS Supply Chain: Maintaining Quality and Patient Safety

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What are the problems facing the NHS?
Over the past 15 years of providing national maintenance frameworks to the NHS, we have seen numerous examples of Trusts having to spend significant sums on repair bills, pre-contract inspections, and parts that were not included in the service contract.

Due to the current economic climate, we are also aware of a number of Trusts taking unprecedented risks with regard to service cover, including strategies such as implementing service contracts on only 50% of a department’s equipment, with the hope that if anything breaks down it will be a covered item. We have also seen a number of instances of extended downtime where regular planned maintenance has been allowed to lapse, resulting in cancellation of patient lists, over-reliance on other equipment, and the added burden on resources from being forced to run weekend and out of hours clinics.

As Trusts are faced with more stringent targets around equipment uptime, ever-increasing patient throughput, and focus on cost efficiency, taking a risk on service cover can be counter-productive. Choosing to downgrade cover on equipment, does not necessarily represent an opportunity to save money: it can represent large repair bills and ultimately mean paying more in a contract year than if the original level of cover was maintained.

New organisations are entering the maintenance arena, with offers of significant up-front discounts for migrating contracts to them, through a managed maintenance service. Whilst big discounts may seem attractive – we would advise all Trusts to investigate the methodology behind the offers: you need to consider whether it genuinely represents the best option for the Trust.

NHS Supply Chain’s approach to minimising risk and maintaining service
We understand the importance of knowing who is maintaining your medical equipment, when your service visits will be provided, and that continuous cover is in place without any breaks. Our national framework agreement for Medical Equipment Maintenance includes 115 suppliers, covering 120 equipment areas; we manage maintenance contracts in 560 NHS sites, and over 40,000 pieces of equipment. NHS Supply Chain conducts a robust tender exercise for every national framework, providing an OJEU-compliant route for Trusts to establish their local service contract requirements.

Our experienced team work with Trust procurement, EBME and clinical teams to help review Trusts’ current arrangements, assess the suppliers and cover levels available and which will be the most beneficial both clinically and financially. We provide information to enable Trusts to make an informed decision.

Increasingly Trusts are looking to take maintenance ‘in-house’, and we believe that you the physicists and medical engineers are the best-placed individuals to co-ordinate this activity. We can work with your Trust to facilitate this and to ensure maximum savings are built into your contracts.

Risk management is becoming an increasingly important topic – the benefit of working with NHS Supply Chain is that you are the masters of your own destiny. We will support you in evaluating all options, but you decide on the level of risk, if any, you are willing to take. We would like to work with Trusts, in conjunction with the relevant clinicians, to ensure the most clinically-appropriate and cost-effective service arrangements are in place and to facilitate innovative ways to reduce costs whilst maintaining existing level of cover.
Supplier specified maintenance routines involve large amounts of work and in the age of NHSLA inspections can be awkward to account to. These routines are sometimes assumed to be necessary and sufficient for safety. It has in the past been advice and authoritative opinion that any variation from model specific recommended routines may potentially expose Trusts to avoidable financial risks through negligence claims. As we represent sovereign public bodies responsible for public money and public safety some scrutiny and some caution may be indicated.

In order to systematically and accountably mitigate these risks to a professional standard, a categorical approach has been in use in our Trust since 2008. This categorical approach to risk based maintenance has many variations but equipment is assessed or scored and maintenance prescribed for group of equipment instead of device model. We have survived NHSLA, CQC and internal audits on this categorical basis. We have had no recorded incidents related to this change of practice.

In this extended form of the scheme we formed a ‘No PPM’ group of equipment categories by assessing the risk of deterioration of performance or safety over time of ‘normal wear and tear’ of all categories of equipment without any corrective maintenance or performance verification. That is, the slowly increasing time dependant risks. We specifically ignored the risks from intermittent high impact damage, misuse and neglect. This super-category was then examined, discussed, edited and pruned briefly in wider professional consultation and a report compatible with normal Trust assurance authorised by routine governance processes.

Whilst many more elaborate risk-based schemes have been proposed in the past, none we know of have the practicality, comparability, speed, effect and future proofing that is potentially provided by this means. This scheme therefore aims to provide something high level and pragmatic that can be implemented rapidly across the entire device population, with scope for later expansion in sub-populations of devices as is appropriate.
How does scheduled maintenance fit into the role of a Services Provider, and what is its affect on patient safety and quality?

We offer an insight into the highly competitive, sparsely defined, and often poorly expectation managed, role of delivering quality scheduled maintenance and how this may affect patient safety.

As a Services Provider, scheduled maintenance is a well defined deliverable, as an outcome, however it is not uncommon that how it is managed and delivered is less well defined, let alone its affect on patient safety.

Services Providers can be part of managing the scheduled maintenance risk, however clarity of what happens to outcomes is required;

Results by numbers.
Results by quality.
How are the results managed;
What was completed and how?
What was not completed, and what happened after this?

Ultimately it how the Services Provider embeds into the entire healthcare organisation, on equipment maintenance and management, that can assist in improving patient safety and the management of quality, and this requires active co-operation from all parties.
Development of an anthropomorphic ultrasound shoulder phantom
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Pratik Adsumilli, Karen McCreesh and Tony Evans

Objectives. The Purpose of this project was to create an ultrasound phantom model of the shoulder that was accurate in bone configuration. The main purpose of it would be to measure the acromiohumeral distance (AHD).

Methods. A DICOM CT dataset of a shoulder was used to create a computerised 3D model of the superior half of the humerus and scapula. This was then printed out of DuraForm®PA with a 3D rapid prototyping printer and used as a bone phantom. The bone model was embedded in a compound containing gelatine, psyllium husks powder and chlorhexidine. The gelatine compound was fine-tuned by making small samples for initial testing. The shoulder shape for the gelatine was achieved using a custom-made shoulder-shaped plastic mould which would also double as protective packaging for the model.

Results. The DuraForm®PA had a speed of sound of 1709 ms⁻¹ and the gelatine compound had a speed of sound of 1550 ms⁻¹. The bone phantom’s average AHD measured before embedding with vernier calipers was 9.8 mm. The average AHD measured using the ultrasound machine, was 9.7 mm without the cover and 10.6 mm with the cover.

Conclusions. The materials used had speeds of sound that were well matched to soft tissue and epiphyseal bone. The model proved to be effective due to its realistic ultrasound appearance. Further development may be undertaken to produce a more permanent and durable model with muscle and tendon mimics.
Phase-Insensitive Sensors for Quantitative Ultrasound
Christian Baker, Acoustics and Ionising Radiation Division, National Physical Laboratory, Hampton Road, Teddington  Email: christian.baker@npl.co.uk
Christian Baker, Srinath Rajagopal, Bajram Zeqiri

Introduction
Previous studies have established that phase cancellation has a significant effect on the assessment of osteoporosis using quantitative ultrasound (QUS) [1, 2, 3]. A novel sensor, originally developed as a means of measuring the acoustic output power of medical ultrasonic equipment [4], can operate in both a phase-sensitive and a phase-insensitive mode, potentially allowing the removal of phase cancellation artefacts from QUS measurements. This sensor has been used to assess the broadband ultrasound attenuation (BUA) of two commercial bone phantoms.

Material and Methods
Novel 30 mm diameter polyvinylidene fluoride (PVDF) piezoelectric bi-laminar membrane hydrophones were manufactured and then backed with a highly acoustically absorbent material. The backing material causes heating of the PVDF when exposed to ultrasound, which responds pyroelectrically in a way which is proportional to the rate of change of temperature. Just after the switch on of the transducer, the rate of change of temperature is proportional to the time-averaged acoustic intensity. As the pyroelectric response is thermal in origin, it is phase-insensitive and should therefore be immune to phase-cancellation caused by phase differences in the ultrasound arriving at the spatially-extended sensor, which occurs due to the difference in speed of sound between trabecular bone and marrow [3] and refraction of the acoustic beam. The sensor simultaneously responds piezo- and pyroelectrically. A novel charge amplifier was designed and built which splits and filters the output of the sensor to provide the piezo- and pyroelectric signals separately, such that phase-sensitive and phase-insensitive measurements may be compared.

In order to validate the performance of the new phase-insensitive devices, the broadband ultrasound attenuation (BUA) of a pair of CIRS bone ultrasound phantoms, one 'healthy' and one 'osteoporotic', was measured with the sensors in combination with the amplifier. The phantoms are homogenous and therefore cause little phase-abberation in transmitted ultrasound, so it would be expected that results from phase-sensitive and phase-insensitive measurements would agree.

Results and Discussion
For both phantoms, phase-sensitive and phase-insensitive measurements of BUA agreed well. However, due to transmitter bandwidth limitations and resulting signal-to-noise ratio (SNR) issues, the frequency range over which adequate SNR could be achieved was significantly smaller for phase-insensitive than for phase-sensitive measurement, especially for the more attenuating 'healthy' phantom. On-going work is looking at the improvement of SNR through the use of a noise reference sensor, and the development of phase-abberating phantoms for future experiments.

[4] B. Zeqiri, P.N
When making measurements of diagnostic fields in a scanning tank with a single-layer (coplanar) membrane hydrophone, the live electrical connection is in direct contact with water. Untreated water has a conductivity of approximately 600μS/cm. IEC 62127-1: Ultrasonics – Hydrophones – Part 1: Measurement and Characterisation of Medical Ultrasonic Fields up to 40MHz specifies a maximum conductivity of 5μS/cm when using a single-layer membrane hydrophone. This is achieved through a deionisation process. Sapozhnikov et al (2007) investigated the effect of conductivity on the signal shape produced by a lithotripsy field on a low-cost membrane hydrophone. The peak compressional pressure was found to be insensitive to conductivity, but the peak rarefactive pressure decreased with increasing conductivity with a corresponding change in the shape of the waveform.

Precision Acoustics Ltd (PAL) has been producing membrane hydrophones for a number of years, which are primarily used by ultrasound scanner manufacturers to perform regulatory measurements. A new design of membrane hydrophone has recently been produced which uses a differential structure. These hydrophones have significantly greater sensitivity and a lower noise floor than the standard (single-ended) design, but there is anecdotal evidence to suggest that the signal shape is affected to a greater degree by water conductivity than the standard design. A series of experiments has been carried out to investigate the effect of conductivity at diagnostic pressure levels across the range of membrane hydrophones produced by PAL.

Evaluation of the diagnostic improvement of <70% renal artery stenosis obtained through the use of ultrasound contrast agents

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Renal artery stenosis (RAS) is a common, progressive clinical condition, is the major cause of renovascular hypertension and is now recognized as an important cause of chronic and end stage renal failure (1). Severe renal artery blockages (>70%) have been studied extensively to date using intra-arterial digital subtraction angiography and magnetic resonance imaging; however, < 70% blockages have not been studied. In this study we investigated whether contrast agents could improve spectral Doppler ultrasound’s ability to detect renal artery stenosis of <70%. A normal renal artery phantom (0% stenosis) and 30 % and 50 % symmetrical stenosis renal artery phantoms were developed for the flow experimental studies. The flow experiments were carried out using a physiological velocity (2-40cms-1) and maximum velocity measurements for each of the three anatomical phantoms were determined from Doppler spectrum using an ATL HDI 3000 ultrasound system with a curvilinear transducer with and without contrast agent. Three contrast agents were investigated: two commercially available contrast agents – Luminity (Lantheus Imaging Inc), Sonovue (Bracco) and an agent that was developed in Edinburgh in Dr Moran’s group for high resolution applications. The agents were injected into circulating blood mimicking fluid and maximum and minimum velocities at pre- and post-stenotic regions within the vessels were measured at three time points – prior to injection, 5 and 15 secs after injection of the contrast agent. In addition the effect of the introduction of a 20mm fat-layer on these measurements was also studied.

At 5 secs after injection of contrast agent, measured mean maximum velocity values increased and measured mean minimum values decreased compared to values obtained using blood mimicking fluid at both pre- and post-stenosis regions. After 15 seconds these changes had almost disappeared in 0% stenosis but changes in mean maximum negative velocity values were still evident at higher stenosis. The presence of an oil layer had limited effect on the measurements of minimum and maximum velocity.

Evaluation of imaging quality of medical diagnostic ultrasound scanners based upon void counting in a 3D volume using voids or low echoic cysts

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Philip Coulthard, Georg Doblhoff and Jaroslav Satrapa

This presentation relates to a device to determine the imaging quality of diagnostic ultrasound scanners using the number of voids detected to provide evaluation criteria.

One aspect of overall Ultrasound image quality, is the capability of a scanner to detect small lesions which may present as low echoic structures. The discrimination of low echoic structures (or voids) is more difficult to achieve than showing small high echoic structures. Determining the void detection capability of such systems is important for several reasons:

- Comparing scanners before purchase
- Determining if a scanner is adequate for certain diagnostic purposes
- Continued quality assurance during scanner lifetime
- Evaluating an ultrasound scanner following a repair

A number of quality assurance processes have been used so far, ranging from simple 2D evaluation of a single image to complex evaluation of 3D-volume scans and using the volume data for calculating void detectability ratios (VDR). Any 2D solution is inadequate to test the geometry of the three-dimensional acoustic pulses used.

To provide repeatable patient-independent measurements all these approaches use tissue-mimicking material phantoms (TMM-phantoms). To measure voids, and to be able to compare values measured against a baseline, an a-priory knowledge of the void’s geometry, size and orientation was originally deemed useful (e.g. using spherical or short cylindrical voids with given diameters. This restricts the comparison of resolution to the void sizes offered and often restricts the scanning geometries, that can be tested (Linear arrays are fully covered in most cases).

Another approach is the use of a random void phantom, however it is difficult to obtain useful resolution information from the contrast or VDR-levels, as the void distribution is random and there is no knowledge as to the real size of a specific void.

A visual inspection of the reconstructed transparent 3D-volume image showing the random voids as translucent objects gives a visual impression of imaging quality and how it changes with depth. A higher density of detected random voids indicates higher quality, but does not provide any quantifiable results.

In this presentation we look at how is it possible to overcome the lack of quantifiable results from random void detection, by counting the number of voids detected at each depth. For any VDR-level exceeding the void detectability limit, higher counts indicate a higher resolution. This is because higher counts are effected by smaller voids being detected, not by noise. The void-count thus offers quantitative information for random void phantoms, which practically cover a continuous range of void sizes a maximum void diameter found in the TMM down to the resolution limit of the scanner.
Background and Purpose: Ultrasound scanner preset programmes are either factory set or tailored to the requirements of individuals or groups of users. As a result scanners may be used with different settings for the same application, even on equipment of the same model in a single department. The aims of this study were: i) to attempt to match the performance of 2 Toshiba Aplio scanners, where one was preferred over the other and ii) to assess differences between 6 Toshiba Aplio scanners used for the same application within our organisation.

Methods: The Nottingham Ultrasound (US) Quality Assurance (QA) software was used as a tool for comparison of imaging performance. Images were collected using a Gammex RMI 404GS test object from 6 scanners used for breast ultrasound, using default presets, factory presets and settings matched to a preferred scanner. Lateral resolution, low contrast performance and high contrast performance were measured.

Results: It was possible to match the performance of 2 scanners, where one had been preferred over the other, such that there was no significant difference in measured image parameters. Default presets varied across the 6 scanners, 3 different presets being used. The most used preset (Breast 1204) differed in settings across the 6 scanners, most notably in the use of different default frequency modes: 14 MHz fundamental (1 scanner), 14 MHz tissue harmonic (2 scanners) and 13 MHz differential harmonic (3 scanners). The Breast Factory preset was more consistent across the 6 scanners, the main variation being in dynamic range (55-70 dB); image comparisons showed significant differences.

Conclusions: It is possible to match scanner performance (same model) using the Nottingham US QA software as a verification tool. Ultrasound users should be aware that scanners may not behave in a similar fashion, even when apparently equivalent presets are used. It should be possible to harmonise presets across a service by consensus amongst ultrasound users.
Evaluation of a simple bladder phantom for assessing the accuracy of bladder volume measurements

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Anna Janeczko, Bill Ellis, Christopher MacLeod, & Scott Inglis

Introduction:
Ultrasound bladder scanners are non-invasive devices widely used to obtain volume measurements of the bladder. This information is important for the diagnosis and monitoring of urinary conditions. However, the accuracy of these measurements can vary substantially (e.g. accuracy +/-20%; +/-20ml). Prior to clinical scanning users should verify that their scanners are within calibration. The Medical Physics Department has extensive experience in manufacture of ultrasound test objects using a well-characterised tissue mimicking material (TMM). Using objects with known dimensions it was possible to create a phantom that provides a controlled environment for testing bladder scanners.

Aims:
To design and evaluate an acoustic phantom that could allow the clinical user to verify their bladder scanner measurements are within tolerance limits.

Methods:
Using the IEC agar based TMM, a bladder phantom was manufactured. The phantom contained a wall-less spherical cavity of known volume. A thin foil hemisphere was used to enhance the lower border of the cavity. The cavity was filled with a fluid mixture that had a speed of sound of 1540m/s at 20°C to mimic the acoustical properties of urine at body temperature. The phantom was evaluated using various bladder scanners that measure the volume using both standard and imaging techniques. The phantom was scanned with 8 bladder scanners (See table) repeatedly as per clinical recommendations (3 consecutive scans were performed and averaged to obtain a Mean and standard deviation). Four scanners calculated the volume by detecting the boundary and displayed the volume and representative planes (Type A) and 4 allowed the user to locate, centralise and calculate the volume of the bladder by imaging the area (Type B).

Results:
The actual volume of the cavity was 138ml. The calculated tolerance limits for the majority of scanners were between 90ml and 186ml. The average volumes measured with each scanner is detailed in Table 1.

<table>
<thead>
<tr>
<th>Scanner</th>
<th>Manufacturer</th>
<th>Type (A or B)</th>
<th>Volume (ml) (mean ± Std Dev)</th>
<th>% Difference from Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>BVI2500</td>
<td>Verathon Medical</td>
<td>A</td>
<td>158 ± 2 ml</td>
<td>+14</td>
</tr>
<tr>
<td>BVI3000</td>
<td>Verathon Medical</td>
<td>A</td>
<td>170 ± 2 ml</td>
<td>+23</td>
</tr>
<tr>
<td>BVI6100</td>
<td>Verathon Medical</td>
<td>A</td>
<td>136 ± 2 ml</td>
<td>-1</td>
</tr>
<tr>
<td>BVI9400</td>
<td>Verathon Medical</td>
<td>A</td>
<td>140 ± 2 ml</td>
<td>+1</td>
</tr>
<tr>
<td>Bardscan II</td>
<td>Bard Medical</td>
<td>B</td>
<td>143 ± 18 ml</td>
<td>+4</td>
</tr>
<tr>
<td>PINIT</td>
<td>Echosan</td>
<td>B</td>
<td>124 ± 13 ml</td>
<td>-10</td>
</tr>
<tr>
<td>MD6000</td>
<td>Meda</td>
<td>B</td>
<td>177 ± 2 ml</td>
<td>+28</td>
</tr>
<tr>
<td>PBS v3.1</td>
<td>Urodynamic systems</td>
<td>B</td>
<td>224 ± 16 ml</td>
<td>+62</td>
</tr>
</tbody>
</table>

Conclusions:
We have developed a simple phantom that provides confidence to the clinical user that their bladder volume measurements are within calibration. All tested Type A and most Type B scanners were able to obtain an acceptable volume measurement using the bladder phantom. One Type B scanner found our phantom difficult to image due to the foil layer resulting in a reading that was significantly higher than expected.
We were asked to investigate a clinical incident where a patient had had two carotid ultrasound scans, the second of which, performed on a different machine, gave significantly reduced flow velocities. A further third scan confirmed that the higher velocities were correct. The second machine was a brand new machine only recently installed, with no apparent faults in either the machine or the probes.

Investigation of the fault using a flow phantom revealed that the faulty machine was giving flow values of between 15% and 30% lower when compared to the other clinical machines, all other machines giving the same flow velocities.

Further work showed that the fault lay with the probe. Using the defective probe on a similar machine that was loaned by the supplier gave the same errors, but using another probe on the original machine gave the same flow velocity values as our other systems. The defective probe had passed all our usual quality control checks, but appeared to have reduced sensitivity in the Doppler mode.

The current IPEM ultrasound quality recommendations do not suggest that testing of the Doppler velocity functions is necessary for ultrasound machines, and many manufactures do not test the Doppler accuracy in their routine service checks.

Our experience, where a defective probe led to a clinical incident shows that if undetected such a fault could lead to significant clinical errors. With the role of duplex ultrasound so crucial in the diagnosis of vascular disease, particularly extracranial disease, it may be advisable for centres using Doppler ultrasound to perform Doppler velocity quality control on a regular basis.
QA for diagnostic ultrasound machines using ‘traditional’ tissue mimicking phantoms places great emphasis on measuring axial and lateral resolution and less so on measuring elevational resolution i.e. "slice thickness". Clinicians have long been aware (Goldstein and Madrazo, 1981) that a ‘thick’ beam will give rise to partial volume effects, ‘filling in’ cysts and thickening bladder walls. The results from newer types of phantoms are influenced by slice thickness especially for cyst detection. However, an important trend in ultrasound is the purchase of machines primarily for the guidance of needle placement in procedures such as central line insertions, biopsy, nerve blocks, botox injections and prostate brachytherapy. Most of these procedures are not done by radiologists or sonographers and so practitioners do need to be made aware of relevant image quality factors.

This presentation will review the role of aperture and frequency on slice thickness and illustrate the range of elevational resolution with different types of probes. Examples will be given of ‘in-plane’ and ‘out of plane’ nerve block techniques and what the anaesthetist needs to know about slice thickness. Another example will show the consequences of a poor beam profile on the accuracy of seed placement in prostate brachytherapy (Peikari, 2011) and how this is a significant factor preventing the development of post-implant dosimetry using ultrasound.

References:

Validation of a blood-mimicking fluid for use in a tri-modality flow phantom

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Thomas D. Mackrell, J. A. Evans, S. F. Tanner, A. G. Davies

There is increasing interest in developing a flow phantom which may be used to quantitatively compare the abilities of ultrasound, magnetic resonance imaging (MRI) and x-ray/computed tomography (CT) in the investigation of vascular pathology. As a first step towards developing a phantom capable of such work, a blood-mimicking fluid (BMF) commonly used in Doppler flow phantom studies was tested to ascertain its suitability to be used within a tri-modality flow phantom. The properties of the BMF important for examination in each modality were studied. The acoustic velocity and acoustic attenuation of the fluid were found to be 1543.41ms\(^{-1}\) and 0.053dBcm\(^{-1}\)MHz\(^{-1}\) respectively, agreeing with the published literature values of the BMF. The x-ray attenuation of the fluid was measured using 50kV and 75kV beam energies and closely matched published values for human blood. The T1 and T2 relaxation times for the BMF were calculated at 3T and were comparable to blood. The effect of the nylon particles on the signal gained from the BMF in MRI was negligible. The effect of adding Gd-DTPA contrast agent to the fluid is described.
Accurate quantification and delivery of thermal dose to cells in culture

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HIFU treatments involve raising the temperature of target tissue above 60°C in short (~2s) bursts. It is known that as tissue temperature is increased above physiological levels, shorter exposure times are required to induce a given deleterious effect. The Sapareto-Dewey thermal dose equation links time taken to produce a biological effect at low temperature to time taken to produce equivalent effects at a higher temperature; however, experimental evidence is lacking for short exposures of the order of seconds.

In order to investigate the validity of the Sapareto-Dewey relationship for short high temperature exposures, a heating chamber has been developed for delivery of well controlled thermal doses to live cells in culture under light microscopy observation. The system comprises a transparent electrode applied to a microscope cover slip onto which an 8 well ‘sticky-Slide’ (Ibidi GmbH, Germany) cell culture chamber is attached. This chamber is inserted into a microscope stage with electrical contacts for the application of a current to the electrode to induce heating of cells in monolayer culture on the coverslip.

Thermal doses can be delivered to the cells by applying programmed current-time profiles and using a temperature control unit to raise and maintain the temperature of the chamber above 37°C. Temperature is monitored with fine wire thermocouples. Uniformity of the temperature distribution across the slide has been assessed using thermal imaging. A thermal model of the system in COMSOL (COMSOL Multiphysics, COMSOL Ltd., Cambridge, UK) has also been used to investigate the spatial and temporal variation of heating throughout the system for comparison with measured values and to provide estimates of the power required to reach and maintain the required temperatures.

The transparent electrode allows imaging of the cells during heating. Cells are imaged with differential interference contrast microscopy before, during and after heating. Features such as cell shape and motility are monitored. Fluorescent markers which stain for live, apoptotic and necrotic cells are used at several time points after heating to quantify effects of thermal dose relative to controls.

Preliminary experiments have been performed using HeLa cells grown in monolayer culture in the heating chamber. Changes in cell shape and adhesion began shortly after raising the temperature to 45 ºC; changes were observed to progress during a heating period of 20 minutes and continued to progress after the cells were returned to 37 ºC. Fluorescent labelling applied approximately 30 minutes after heating showed apoptotic and necrotic cells at higher levels than for the control.

Further work will be presented on the effects of thermal dose applied over different temperatures and time periods.
High frequency ultrasound: phantom development, contrast agent characterisation and small animal imaging
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Introduction: The range of applications of high frequency ultrasound (>20MHz) both clinically (intravascular and superficial tissue imaging) and in the life sciences has increased dramatically in the last 10 years especially in the field of preclinical imaging. This study investigated the attenuation and speed of sound of a tissue mimicking material (TMM) utilised in a resolution test phantom that has been developed for the assessment of the imaging performance of high frequency ultrasound transducers. In addition the attenuation and contrast to tissue ratio (CTR) and subharmonic to fundamental ratio (SFR) of two commercially available UCAs: Definity (Lantheus Medical Imaging, USA), and SonoVue (Bracco Group, Italy) and a preclinical UCA: MicroMarker (Visualsonics, Canada) were measured to assess their applicability for preclinical imaging applications.

Methods: Acoustic measurements of both TMM and contrast agents were performed using the RF data from a Vevo 770 preclinical ultrasound scanner (Vevo 770, VisualSonics Inc., Canada) using 4 transducers (710B, 707B, 704 and 711) over a frequency bandwidth of 12-43MHz. Additionally the acoustic properties of four test samples of TMM were additionally tested using a scanning acoustic macroscope (SAM) with a broadband immersion transducer with centre frequency of 50MHz. Attenuation over the 3dB bandwidth of each of the transducers was measured using a broad-band substitution technique. Contrast-to-tissue (CTR) was referenced to the TMM. The contrast agents were diluted to a concentration of 0.8 x10^6 microbubbles /ml.

Results: The speed of sound in TMM over the frequency range 12-47MHz was calculated to be 1547± 1.4ms⁻¹ using the Vevo 770 transducers and 1548.0±6.1ms⁻¹ using the SAM system. The attenuation of the three contrast agents varied by approximately 2dB.cm⁻¹ over 12-43MHz bandwidth compared to the attenuation of TMM which was found to vary with frequency as 0.40f+0.0076f². over this same bandwidth. At these frequencies the three contrast agents demonstrated similar CTR but Micromarker demonstrated significantly higher SFR.

Conclusion: Three lipid-encapsulated microbubbles were investigated for their applicability for use in preclinical studies. Definity and SonoVue which are marketed as clinical contrast agents, showed similar results for attenuation, CTR and SFR over the 12-43MHz bandwidth of the transducers. MicroMarker, which is marketed as a preclinical contrast agent, demonstrated significantly higher SFR, thus demonstrating its utility for high frequency imaging when sub-harmonic imaging is available.
The acoustic pressure field from a commercial sonoporation device, the Sonidel SP100 was measured in water using a 0.5mm diameter needle hydrophone. In order to examine the effects of reverberation on the acoustic field, measurements were made with an acoustic absorber, Apflex 28, and a radiotherapy mould material placed just beneath the tip of the hydrophone. The experimental results were compared with results obtained from a standard theoretical model for a circular plane piston source operating under linear driving conditions. The role of reverberation artefacts arising from the long pulse lengths used by the SP100 will be discussed. Pressure measurements were also made behind the calf muscle of a mouse model which was undergoing sonoporation tests as part of research investigating gene transfection using ultrasound and microbubbles. Measurements were made with and without microbubbles and plasmid injected into the calf muscle. The peak negative pressure measured behind the calf muscle was typically 0.5 MPa +/- 0.15 MPa. Although there was no significant change in the pressure measured with and without microbubbles present in the calf muscle, there was some evidence of stable cavitation through the detection of non-integer harmonics in the acoustical signal.
Developments in a secondary solid-state pyroelectric method for measuring
diagnostic-level acoustic output power
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Hampton Road, Teddington, Middlesex, TW11 0LW
Email: srinath.rajagopal@npl.co.uk
Srinath Rajagopal and Bajram Zeqiri

Background, Motivation and Objective
Total acoustic power produced by medical ultrasound transducers is a key quantity used to
describe the thermal hazards and patient safety. International standards require the
measurement of attenuated acoustic output power emerging from an aperture of unit
dimension to estimate the thermal index (TI). One key aspect of device quality
assurance/quality control purposes in a hospital environment is to enable the user to verify
TI values independently against displayed values seen on all modern diagnostic devices.
However, the diagnostic powers that need to be measured are usually in the range 1 mW to
a little more than 100 mW. Measuring such powers using traditional radiation forces balance
within a hospital environment is difficult due to a lack of available devices, mechanical
vibration and the careful setup required in making useful reliable measurements. To address
this requirement, NPL has developed an ultrasound power meter based on solid-state
pyroelectric method which might form the basis of a relatively easy to use, portable meter
providing traceable measurements of acoustic output power.

Methods
A power measurement concept based on pyroelectricity generated within a thin layer of
polyvinylidene fluoride (pvdf) has been previously described (1). A device based on this
principle, capable of measuring total acoustic power from physiotherapy acoustic fields to
better than ± 20%, is commercially available (2). NPL has now extended the method to
enable diagnostic-level power measurements through the use of a large area pvdf sensor
and dedicated electronics. A number of key performance characteristics have been
evaluated such as its frequency response covering the range 1.5 MHz to 10 MHz, directional
response of the sensor, effects of temperature, and a dual sensor configuration to
investigate background vibration cancellation and overall linearity.

Results
The sensor and electronics module comprising the diagnostic-level power meter will be
described and performance validation studies presented. The technique is very sensitive,
with a power to voltage conversion factor of typically 0.23V W−1. The frequency response is
flat to within ± 4% above 2.5 MHz; below 2.5 MHz the sensitivity falls by 20% at 1.5 MHz.
The linearity of the sensor was found to be within ± 1.6% for applied powers in the range
1 mW and up to 120 mW. The rate of change in sensitivity with ambient temperature over
the range 20 °C to 30 °C was found to be +0.5% °C−1. Measurements obtained on a
limited number of clinical diagnostic fields will be presented and compared with radiation
force methods, with an agreement typically better than ±10% being demonstrated.

(1) Zeqiri B, Barrie J, "Evaluation of a novel solid-state method for determining the acoustic
power generated by physiotherapy ultrasound transducers", Ultrasound Med Biol. 2008 Sep;
34(9):1513-27.
The ‘in-air’ reverberation technique has been widely accepted as a standard test method in ultrasound QA [1, 2] indicating image uniformity, imaging system noise level and system sensitivity. Our experience has shown that the technique is effective and efficient in revealing image uniformity of linear array transducers and in indicating system noise level. However, when it comes to the system sensitivity, the depth of the ‘in-air’ reverberation pattern seems not efficient enough to represent the sensitivity.

This talk intends to share our experience and to raise this issue for further discussions by presenting some case studies on the technique applied for tests of image uniformity, system noise and system sensitivity.

For the image uniformity, the air reverberation (AR) patterns were obtained from two PVT-375 transducers (one of which was brand new and the other had badly element drop-out) on a Toshiba Apio XG scanner and from a C5-1 transducer (which lens was partially delaminated) on a Philips iU22 scanner respectively. The correlation of the AR pattern and the transducer status were observed.

For the system noise, the noise values obtained by using the technique with transducers of same model but of different ages on a Toshiba Apio XG were compared to see the consistency of the technique in indicating the system noise.

For the system sensitivity, relations between the air reverberation depth (ARD) and parameters representing the system sensitivity (e.g. acoustic power, receiver gain and low contrast penetration when imaging a tissue mimicking phantom) were examined on a Philips iU22 scanner and a Toshiba Apio XG scanner.

The results shown that while the ‘in-air’ technique worked well for the uniformity test and the noise test, the technique using ARD to indicate sensitivity changes was not straightforward. While in general the ARD was positively related to the system sensitivity, the ARD did not always follow the change. This observation may suggest that the ‘in-air’ reverberation technique is more suitable for the image uniformity test and the noise level test than the sensitivity test. More investigations on the relation between ARD and system sensitivity are necessary when using the air reverberation depth to indicate a system’s sensitivity.

A review of routine quality assurance on a cohort of machines at BSUH NHS Trust

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A quality assurance protocol was developed at BSUH NHS Trust incorporating the based practical experience of testing, equipment, and hardware/software availability and incorporation of guidance from IPEM Report 102.

Routine testing was conducted annually throughout the clinical lifetime of a cohort of eleven Aloka Prosound Alpha 10 units used in several clinical specialisms. Tests included calliper accuracy and geometric distortion, crystal dropout, sensitivity and noise tests. Images were captured to allow analysis using the QA4US software (Thijssen, Weijers and De Korte, 2007) to give measurements of dynamic range, beam penetration and axial and lateral resolution.

Results mostly show the consistent performance of machines throughout their clinical lifetime. However, the frequency of crystal dropout increased with time requiring probe replacement. Some parameters drifted over time, but it is difficult to assess the clinical significance of such changes.

The results obtained attempt to contribute towards addressing the ongoing limited evidence base of the effectiveness of routine quality assurance testing. Questions arise regarding the function of QA as a measuring tool or a tool to ensure physics input to clinical ultrasound and need to link testing more closely to the clinical use of machines.
Reproducibility of aortic aneurysm screening measurements: how does it depend on signal processing?
Rachel Weston Smith, University of Leeds, Leeds   Email: um09rws@leeds.ac.uk

Rachel Weston Smith, Stephen Wolstenhulme and Tony Evans

Introduction
As the National Screening Programme for Abdominal Aortic Aneurysms (AAA) becomes fully implemented across the United Kingdom, questions are raised about overall reproducibility in relation to the quality of the images and the method of measuring the aortic diameters.

The aim of this project was to assess the impact that manipulation of abdominal aortic ultrasound (US) images has on the intra-observer reproducibility of the diameter measurement compared to that of the original image. The study compared variability between inner-to-inner (I-I), outer-to-outer (O-O) and outer-to-inner (O-I) wall diameter measurements and their resilience to being manipulated.

Methods
Three US images of transverse abdominal aortas, selected by the Keeble et al. 2013 study (in preparation), were manipulated in 13 different ways using functions from Image J software. Blinded measurements were then taken of the aortic diameters from each image in a random order; this was repeated for I-I, O-O and O-I diameter. Profile plots of the three images were produced and algorithms developed to provide detailed instructions as to where on the plot the callipers should be placed to correspond with the placement of the callipers on the actual image. Statistical analysis was then performed on the results to show any correlations.

Results
The reproducibility of the diameter measurements was found to be least affected by manipulation of the Brightness and Contrast of the US images (better than +/-1.5mm). Using the functions ‘Sharpen’ and ‘Find Edges’, created the largest difference; up to -5mm from the reference length. The I-I measurements had the widest spread of variability, whereas the O-I measurements proved to be the most reproducible, and therefore most resilient to the manipulations.

Conclusion
Manipulating an image can both increase and decrease the reproducibility of the diameter measurement, depending on the original quality of the image and the function by which it is manipulated. Altering Brightness and Contrast may hold the key to improving aortic US images and therefore the accuracy of the diameter measurements without affecting their reproducibility. Further research could expand these results and transfer them into the clinical setting of the National Screening Programme to increase its reliability.
There has been a big improvement in the quality of ultrasound scanners and angiographic imaging over the last 15 years. The duplex criteria used to grade carotid disease has been standardised. In spite of these improvements there remain disparities in the results of carotid imaging as seen at the MDT meeting. The results of an audit of imaging and an audit of the duplex criteria used will be presented within a discussion looking at where problems remain.
Quantitative Image Testing
Wednesday 5th June

Experiences of Quantitative Image Quality Assessment
Ben Johnson, Radiation Safety, Barts Health NHS Trust, London, EC1A 7BE Email: ben.johnson@bartshealth.nhs.uk

The Radiation Safety Section at Barts Hospital has been using the in-house ObjIQ tool to generate modulation transfer functions (MTF), noise power spectra (NPS), uniformity analyses and variance mappings since 2004.

These detector performance metrics are now measured at every routine visit and form an integral part of equipment quality assurance on direct digital radiography (DDR) and computed radiography (CR) systems.

Over the years, a large database of results for most detector types has been accumulated and this has dramatically increased over the last four years as almost complete implementation of DDR has occurred across the trust and client sites. Results for a number of systems will be presented to demonstrate notable events and trends in results and how this has informed reporting to end-users and engineers.

Some of the issues discovered during the period of making routine quantitative image quality measurements will be discussed and how testing methods have developed from experience of using these tests. Certain detectors have proved more demanding to test and the difficulties encountered with some specific systems will be reflected upon. The use of in-built manufacturer tests will also be briefly discussed.
The Supplement to the European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis (4th Edition) was published in 2010 and proposed a new and more sensitive approach to noise evaluation, namely splitting total measured image noise into its constituent components: electronic, quantum, and structured noise. These guidelines were specifically intended to apply to QA in Full Field Digital Mammography, but we have applied the same noise analysis technique to QA measurements on DR and CR equipment where export of raw DICOM images is possible. Analysis has also been carried out on some radiotherapy kV imaging systems.

As part of routine QA for all systems we routinely measure the STP relationship of pixel value to dose under standard beam conditions. Automated software is used to place a measurement ROI at a central position in each dose image for this purpose. Measurement of pixel value standard deviations from the same regions of interest is trivial, and so we can perform analysis of noise components in an Excel spreadsheet using information from the same image set.

Comparison of the overall relationship of noise versus air kerma to baselines is carried out, as suggested in the 4th Edition of the European Guidelines. Pixel standard deviation or signal-to-noise ratio at a reference air kerma is also compared to baseline values. Tolerances on the analysis of noise components will be discussed.

Results of these measurements over time will be presented for different manufacturers and systems with linear, log and power pixel value responses, and measurement and analysis problems will be discussed.
Measurement of Quantitative QA parameters for Digital Mammography
Nicholas Marshall, Department of Radiology, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium  Email: nicholas.marshall@uzleuven.be

The availability of DICOM 'For Processing' images has facilitated the use quantitative measures of image quality, such the pre-sampling modulation transfer function (MTF), noise power spectrum (NPS) and the detective quantum efficiency (DQE), for routine assessment of mammography detectors. This talk discusses current guidance on the measurement of these parameters and the steps required for their estimation. Some influencing factors are explored: size and position of the edge for the MTF, energy used for the MTF acquisitions, purity of the Aluminium sheet for flood image acquisition. Linearization and normalization of the noise power spectrum is examined. Finally, the repeatability of x-ray output, detector response, MTF and NPS was measured for one digital mammography system over five consecutive days. The coefficient of variation (cov) for the MTF (averaged up to the Nyquist frequency) was 1.6% while cov for the NNPS was 3.2%. The resulting cov for the DQE was 4.4%.
For many departments wishing to undertake quantitative quality assurance (QA), such as the pre-sampling modulation transfer function and noise power spectrum, the time associated with carrying out these tests can be prohibitive. There are also concerns about what the results tell us, as well as what to do with results that appear to be ‘out of tolerance’.

The aim of this talk is to discuss the quantitative QA measurements we have done in Hull over the last five years, namely how we carry out these tests and how we have fitted them into our annual routine surveys without a significant increase in the time spent on any given system. We have experience of measuring MTF, NNPS, SNR and variance routinely for CR, DR, Mammography FFDM, kV radiotherapy imaging systems and MRI systems; typical results and pitfalls will be presented.
Practical experiences of quantitative QA
David Platten, Medical Physics, Northampton General Hospital NHS Trust, Billing Road, Northampton, NN1 5BD  Email: david.platten@ngh.nhs.uk

This presentation illustrates some problems that have been encountered when making quantitative QA measurements as part of the routine testing of x-ray imaging equipment. Probable causes and possible solutions will be discussed. The topics will include: unexpected variation in the modulation transfer function measured from computed radiography images; changes in signal transfer properties and noise power spectrum due to an image artefact; changes in nominal 10 μGy noise power spectrum results from year to year; and initial experiences with noise component analysis.

Software choices for performing quantitative QA
David Platten, Medical Physics, Northampton General Hospital NHS Trust, Billing Road, Northampton, NN1 5BD  Email: david.platten@ngh.nhs.uk

This presentation will discuss software that can be used to help with quantitative QA. It will cover choices of programming language and whether to use a ready-built system or write your own. The advantages and disadvantages of some packages will be discussed, including ImageJ macros and plugins, IQWorks, OBJ_IQ_reduced, the dcmtk utilities and IDL. The speaker will describe which tools he uses and why.
Quantitative QA: The hard part...
Tim Wood, Radiation Physics Dept, Hull and East Yorkshire Hospitals NHS Trust, Queen's Centre for Oncology and Haematology, Castle Hill Hospital, Castle Road Cottingham, East Yorkshire, HU16 5JQ   Email: tim.wood@hey.nhs.uk

For many departments wishing to undertake quantitative quality assurance (QA), such as the pre-sampling modulation transfer function and noise power spectrum, the most difficult task is not the detailed analysis of the results as many freely available software packages are now available for this purpose; it is the acquisition of images in the correct format for analysis and the transfer of these to the appropriate software that often proves most challenging.

Many digital imaging systems are set up purely with clinical use in mind, and often do not present easy or obvious options that allow the acquisition of un-processed flat field images for quantitative QA (though digital mammography equipment normally have these easily available due to the well established UK/European requirements for QA). Equally, manufacturer guidance on how you can access the hidden settings for acquiring and exporting un-processed images is extremely variable, and is often met with the response that 'you are the first to ask us that…'

The aim of this talk is to discuss some general and system specific methods of accessing correct image formats across a range of modalities, and how users can get these into the appropriate software for analysis (note, software options are to be discussed elsewhere). Further to this, a proposal for the collation and sharing of a much wider range of user experience will be discussed to ensure we know that we are no longer the first to ask the difficult question!
The use of variance images in the detection of artefacts in CR and DR images, and evaluation with quantitative methods
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Methods of enhancing the information gained from surveys of CR and DR imaging systems whilst minimising impact upon survey time have been investigated. Using images already acquired in routine tests of these modalities, variance images have been generated, using a macro written in ImageJ (free software written in Java), for a range of computed radiography (CR) and digital radiography (DR) x-ray detectors, all at a wide range of air kerma. Artefacts have been identified in variance images, that would otherwise likely have been missed in routine QA. An evaluation of the variation of the artefacts with air kerma will be presented, the cause of which is under ongoing investigation.

IQ works and OBJ_IQ reduced (both free software for objective image quality analysis) have been used to enable measurement of the noise power spectrum (NPS) and modulation transfer function (MTF). Protocols for implementing these checks efficiently into the routine QA programme are under development. Findings will be compared to those of established subjective methods for assessing image quality. The NPS has also been retrospectively calculated to assess the degradation of detectors from commissioning checks.
The use of quantitative QA during acceptance and commissioning of DR

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NHS Tayside has recently procured and installed its first two DDR systems. In addition to the usual tests recommended by IPEM report 32 VII for acceptance and commissioning, quantitative tests were performed.

This was the first time that MTF, NNPS and variance images were used on DDR systems by Ninewells Hospital’s radiation physics department and we have encountered some problems. Whilst having been able to obtain results for all tests, we found it difficult to interpret the results. This was most likely due to a lack of experience with these tests and their results, but it was compounded by some lack of manufacturer data.

Cooperation with colleagues around the country has given us some comparative data to use, and allowed us to better understand our own results. The presenter stresses how important cooperation between physics departments is, especially when dealing with unfamiliar equipment and equipment that is new to the market.
Background
At the Royal Surrey Country Hospital (RSCH) we started using a Deep Inspiration Breath Hold (DIBH) technique in June 2012 to treat left sided breast patients, and currently perform around 100 fractions per month. To achieve this, we use the Varian Real-Time Position Management (RPM) system with Video Goggles both at CT and treatment. Through its use, we have encountered a number of hurdles along the way, both while initially setting up the system, and following clinical implementation. We have rectified all problems faced to date and hope that sharing our solutions and practices will be useful for those who use the system for similar techniques.

DIBH Method & Issues Identified
At the RSCH the RPM system is in clinical use on 2 treatment linacs and a single wide-bore oncology CT scanner. Infrared (IR) tracking cameras record the motion of a reflective marker block which is positioned at the base of the patients sternum. The block is tracked during CT acquisition, with planning scans taken during breath hold. Breathing amplitude thresholds are set during the CT session. These are imported at treatment to ensure the patients breath hold and positioning is reproduced during treatment delivery.

A number of issues have been identified throughout the process including:
Breath hold duration and stability
Patient understanding / training
Incorrectly acquired traces causing treatment delays

Solutions Implemented
Training of staff and coaching of patients was identified as a priority. The patients understanding of the procedure prior to the planning scan is important and was highlighted after a particularly challenging treatment leading to stricter eligibility criteria. Procedures have been devised to rectify incorrectly recorded traces, and allow identification of the cause.

Measures are now in place which ensures that the trace acquired at CT is then correctly imported at treatment, thus meaning that DIBH should not be the cause of treatment delays.

Conclusion
Through the implementation of DIBH for breast treatments at the RSCH we have identified a number of key points which help eliminate problems which may arise when using the Varian RPM system. The system can be used with little involvement from physics following initial setup, and all challenges encountered have been resolved.
Second Cancer Risks after Radiotherapy for Breast Cancer: What is the Impact of Advanced Treatment Techniques?

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PLEASE NOTE:
This work has been presented previously at the 2nd ESTRO FORUM, Switzerland, 2013.

Background and Purpose
Breast cancer is the most commonly diagnosed female cancer, and with good survival rates, it is imperative that any potential long term side effects from this effective treatment are reduced. Techniques specific to patient cohorts with differing risk factors are likely to be the new standard of care in breast radiotherapy in 5 to 10 years. These techniques include simultaneous integrated boost (SIB) and conformal non co-planar beam arrangements for accelerated partial breast irradiation (APBI). These beam arrangements distribute the dose throughout the body in a different pattern to the standard treatment. This work reports a comparison of the risk for these modern radiotherapy techniques (including image guidance).

Methods
Five treatment plans were created on a patient CT scan: standard whole breast treatment (WBRT), conformal non co-planar five field plan for an APBI treatment, two volume/two dose level SIB plan with 5 fields, three volume/three dose level SIB plan with 7 fields (forward planned), three volume/three dose level SIB plan with 7 fields (inverse planned). The plans were transferred to a whole body phantom. Regions in the phantom which represented radiosensitive organs were delineated and thermoluminescent dosimeters (TLD) used to measure the dose. Dose from a breast imaging kilovoltage cone beam CT protocol was measured with TLD in the same regions. These dose data were used as input into the Biological Effects of Ionising Radiation Report VII models of second cancer induction and lifetime risks calculated for the five treatment classes and intensive imaging regimes.

Results
The lifetime risk data showed that complex radiotherapy techniques did not increase the theoretical risk of second cancer incidence for organs distant from the treated breast, or the contralateral breast where appropriate constraints were applied. SIB treatments were predicted to increase the lifetime risk of second cancer incidence in the lungs compared to standard breast radiotherapy; this was outweighed by the threefold reduction in 5 yr local recurrence risk with adjuvant radiotherapy for a high risk cohort for whom these treatments are appropriate. A lower lifetime risk of second cancer in the contralateral breast was predicted for the APBI method, compared with WBRT. The contribution of imaging dose to the total dose from both treatment and imaging did not exceed 22% for any measured organ.

Conclusion
Modern complex radiotherapy techniques used in breast cancer were not predicted to increase the theoretical risk of second cancer incidence in organs far from the treated breast. Where increases in the lifetime risk of induced second cancer were predicted, these remained small compared to the large reduction in local recurrence risk from receiving RT as a component of treatment. The use of image guidance is unlikely to result in an unacceptable increase in second cancer risk.
In the developing countries of Africa, cancer is of growing concern. Whilst radiotherapy continues to play a major part in the fight against this disease, this treatment modality is relatively undeveloped in Africa.

Radiotherapy services are not available to a majority of patients due to location of centres or financial constraints amongst others. Patients who have access to a department are faced with a service which is ill equipped and lacking in adequately trained personnel.

The aim of our project is to apply the resources and expertise for cancer treatment that we have in the UK to assist healthcare professionals in developing countries.

Our preliminary aim for 2012 was to undertake a fact finding trip to ascertain exactly what resources are available to the departments and what challenges are faced.

This trip occurred in May 2012 and was what can only be described as a mind blowing, humbling experience. Patients experience horrendous travel times and that is if they can afford to fund their treatment at all. They are faced with machines that regularly break down. One of the departments had no simulator or CT scanner for planning. The oncologists have the challenge of prescribing treatments on machines where the required dose cannot be achieved due to beam parameters. There is limited QA or PPM on the machines and what is scheduled is performed by self taught engineers.

Despite amazing, dedicated staff, the 2 government departments visited were very sombre places. The majority of patients present with late disease due to lack of public awareness. Many patients only present to the oncologists when the spiritual healers feel they have achieved all they can or progression of disease causes pain.

The long term aim of the project is to develop a training programme for all staff to enable them to fully utilise the equipment available.

This presentation will discuss the findings of the fact finding trip in more detail and the development of the project since our return to UK.
At the Oxford University Hospitals NHS Trust, a range of paediatric nuclear medicine examinations are carried out with technetium-99m and iodine-123, including bone scans, renal DMSA and MAG3 scans, Meckel's scans, hepatobiliary iminodiacetic acid scans, thyroid scans and MIBG scans. An audit was carried out of the doses given, in terms of activities administered, to paediatric patients in the Nuclear Medicine department at the John Radcliffe Hospital from July to December 2012.

Data for this period was taken from the Radiology Information System: patient height, weight and administered activity were recorded. The activity administered was compared with the required dose, calculated by two different methods. The first was based on the patients' measured heights and weights and scaling based on a calculation of body surface area, and the second used measured weights only and data from the “Notes for Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Radioactive Sources” published by the Administration of Radioactive Substances Advisory Committee (ARSAC) (2006).

The differences between the calculated and administered activities were found and plotted in histogram form, and compared with the Oxford University Hospitals tolerance of 10% difference from calculated activity. The administered doses were also compared with adult dose levels and the ARSAC diagnostic reference levels.
The spatial resolution of a pinhole collimator is superior to that of a parallel hole collimator. Due to the magnification of objects close to the aperture, the pinhole collimator lends itself to imaging superficial organs such as the thyroid gland. A disadvantage of the pinhole collimator is the difficulty in obtaining quantitative measurements due to its distance dependent sensitivity. An estimate of thyroid trapping is important in deciding the best clinical pathway for the patient and helps clinicians determine the correct treatment activity if radioiodine is indicated.

A protocol for thyroid imaging has been created and put into use at the Kent and Canterbury Hospital whereby the pinhole collimator is used to obtain a reliable estimate of the percentage of injected 99mTc pertechnetate trapped in the thyroid 20 minutes post injection. The protocol relies on a measurement of the distance between the skin and the collimator to obtain a sensitivity factor. This allows the operator to bring the collimator as close as possible to the neck to optimise the image quality.
Neonatal jaundice is a common condition in newborns which will either resolve naturally or can be treated if there are concerns about the level of jaundice. Excessive jaundice can lead to brain damage. In 2010 the National Institute for health and Clinical Excellence (NICE) published a clinical guideline, CG98, on the treatment of neonatal jaundice. The main recommendations were to monitor newborns closely and to measure the level of bilirubin for every case of visible jaundice. This implies a large increase in testing.

The amount of total serum bilirubin (TSB) in the bloodstream can be measured with blood obtained from a ‘heel stick’ technique. For screening purposes a non-invasive method would be preferable, though a TSB will always be used to confirm the result of a non-invasive method of estimation if it indicates that the level of jaundice is too high or if such a method is not appropriate.

Non-invasive methods include visual estimation, the Gosset icterometer and the Transcutaneous Bilirubinometer (TcB). These methods are illustrated.

The manufacturer of one type of TcB recommends that the device is periodically validated by finding a baby who is going to have blood drawn for some reason, making a TcB measurement and comparing this to the TSB measurement. In practice it is a very time consuming process to find enough babies with the right criteria to obtain readings through the whole range of measurement to be statistically valid. This prompted the development of an optical radiation phantom for validation purposes and the process and results are described in this presentation.
In recent years quantitative image quality analysis has been rapidly adopted by the Radiology Physics community in line with the rapid growth in digital imaging technology and the publication of IPEM 32 part VII: Digital Imaging Systems. Many departments are now collecting quantitative measures of resolution and noise through mathematical functions such as modulation transfer function, variance map images, normalised noise power spectrum alongside usual subjective measures from scored images of test objects. We have adopted this approach locally in our work for the Oxford University Hospitals Trust. This presentation seeks to demonstrate the value of these new metrics by highlighting a particular case in which normalised noise power spectrum analysis was usefully applied to both highlight and confirm resolution of an image quality problem encountered on an under-table digital radiographic system.
Originally the Helical TomoTherapy HiArt machines operated without an integrated dose control system. This resulted in instability in dose rate over time. Since going clinical on our first HiArt in May 2006, and our second machine in 2007, our experiences were that the machines had numerous dose related interruptions. We constantly had to adjust machine output and in some cases the dose instability compromised the dose delivered to patients.

In 2011, as a response to customer requests, Accuray introduced the Dose Control System (DCS) as part of their improvement to both treatment quality and machine performance of the Helical TomoTherapy HiArt machines. The Bupa Cromwell Hospital was one of three sites in the UK to test the system before its full release in 2012. Dose control is achieved by: controlling the RF power based on feedback from the monitoring ion chambers in the head of the machine; controlling the gun current with feedback to the injector gun assembly.

Improved output stability has reduced rotational variation with gantry angle and dose drift with time.

An additional aim of Accuray was to reduce dose rate related interruptions and not to increase dose control beyond currently stated tolerances.

With DCS operating the peak to peak rotational angular variation is routinely maintained within ±1% for the treatment beam and dose drift over 15min is typically within ±0.5%.

There has been improved dose rate stability and reproducibility with the DCS, which is evident in the routine output checks we perform. Patient treatment quality assurance reflects the now stable machine output and significant patient to patient doses differences due to output instability are no longer observed. We will present data illustrating these.

The MVCT beam, however, has not enjoyed a similar improvement to the rotational variation with gantry angle. Implementation of a narrower imaging jaw width was a requirement for the trial DCS, which has resulted in increased dose of about 36% to patient during MVCT. The effect of long term dose stability on MVCT image-density table is still being analysed and initial results will be presented.

We will also present data on whether Accuray has been able to reduce dose rate related interruptions with DCS.
Clinical application of an automated structure outlining system (ABAS2.01)

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Accurate and reliable segmentation of volumes is an essential step in external beam treatment planning and dosimetry. At the Royal Berkshire Hospital (RBH), manual/conventional segmentation method, regarded as ‘gold standard’, is used routinely. This procedure is tedious, time-consuming, and not always reproducible. Atlas-Based Auto-Segmentation (ABAS) system is an auto-contouring software, developed by Elekta. ABAS uses one atlas or multiple atlases with defined structures as templates to predict clinical target volumes (CTV) and Organs at Risks (OAR) in a planning CT dataset. The goal of this project was to commission and evaluate ABAS performance for target volume and structure delineation in prostate treatment planning and to assess the possible dosimetric implications. The effects of hip prosthesis, image noise and artefacts and the variability in contouring between clinicians was also investigated.

Comparative analysis of ABAS and manually-contoured structures of prostate patients was performed using the Conformity Index evaluation metric in ImSimQA (OSL) software. The same principle was used to quantify agreement of all contours in this project.

ABAS produced satisfactory results for large and well-defined anatomical structures such as the femoral heads with a contrast value greater than 300 HU. Small structures, such as the Penile Bulb (PB) could not be defined precisely due to high anatomical variability among patients and poor contrast of soft tissue structures in the planning CT (contrast value of 10 HU). The discrepancies between ABAS and manual contouring were expressed as mean Conformity Index (CI) and values in the range 0.33 (worst agreement for the penile bulb) to 0.71 (best agreement in femurs) were obtained. The agreement between ABAS and manual contours is comparable to the level of variation in volume delineation usually observed between clinicians. Generally, ABAS offers a significant time-saving over manual method in contouring of structures up to 48.7%. Delineation of clinical target volumes CTVs by ABAS is substandard due to lack of well-defined boundaries and edges. The performance of ABAS tends to deteriorate in the presence of noise and artefacts. The threshold of noise strength below which ABAS has an acceptable performance (CI > 0.7) varies from 10 - 40% depending on the structure under investigation. This effect is most significant in low-contrast structures, such as the penile bulb. The Conformity Index for bladder, bulb, rectum and body are not affected significantly by the presence of the hip prosthesis. For the left and right femoral heads there is a drop in agreement in CI by 45% and 60% respectively due to their anatomical position (in the artefact area).

Anatomical structures in the pelvis area can be auto-segmented by ABAS software very accurately to within 2 mm of manually delineated structures. The overall result shows that ABAS offers a considerable reduced time for contouring of normal tissues which can be a potential benefit for IMRT planning and additional potential to improve consistency and efficiency. The auto-segmentation software, however is yet to meet the challenge of eliminating an expert outline of clinical target volumes. Additional Clinician time is required for editing of CTV volumes and OAR produced by ABAS but still produces a time saving of up to 50% in comparison with time to perform manual contouring.
POSTER: A Report on the Initial Experience of the BARD 'Prolink Brachytherapy System' in the Treatment of early stage Prostate Cancer

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S. Thompson, J. Nevinson

Permanent Implementation of Iodine-125 seeds using transperineal ultrasound guided brachytherapy is a well established treatment technique in the management of early stage prostate cancer.

This poster describes practical implementation and initial 10 month's experience of the Bard One-Step Interoperative Prolink technique at University Hospital Southampton NHS Foundation Trust (UHS); the first UK hospital to adopt this technique. Switching from traditional implant methodology with uniformly spaced stranded seeds, the first Prolink technique patients were treated here in June 2012. Since then, 33 patients with prostate gland sizes varying between 21.5 and 50.1 cc, were implanted using the new technique, which consists predominantly of peripherally loaded STM1251 seeds, plus a few internal placements, according to gland size.

In procuring a new clinical service, key objectives were: to move to a product that would promote a streamlined fully dynamic one-step implant process, allow non-uniform seed spacing, reduction in the number of implant needles, & provide good visibility on ultrasound imaging; in turn enabling precise longitudinal plane screen-capture of the seed drop.

An innovative feature of Bard Prolink is to produce variable spacing seedtrains in any 0.5 cm configuration. A substantial reduction in the number of implant needles is possible without compromising adequate dose coverage of the prostate(1). Using fewer needles (around 30% compared with traditional technique), reduces oedema and has the benefit of reducing the procedure duration.

SourceLink connectors linking 125 I seeds, are slow absorbing, remaining structurally intact for 170 days, so that the majority of the dose is delivered whilst seedtrains remain in place.

The QuickLink Loader pictured here composes the seedtrains in a sterile environment, in configurations to match the Needle Loading Report of the Variseed (V8.0) Inverse Planned Brachytherapy treatment. 125 I seeds and 3 separate cartridges of different Link styles slot into the Quicklink carriage, dispensing into individual seedtrains at a button touch.
Ultrasound visualisation of the Prolink System has been excellent. Whilst some credit goes to the improved quality longplane image of a newly acquired FlexFocus, the most striking feature is the appearance of the Links, resembling a bold ‘=’ in longplane view. Easier to identify than seeds, Links allow very accurate capturing of the seedtrain drop from each needle, and hence reliable Online Plan live update. Each needle within the plan should contain some Links, to improve visualisation as well as spatial dose distribution.

One shortcoming of Prolink Seed Assay to satisfy UK standards has been notified to Bard, and we are assured that an improvement will be made: Currently the workaround is to place each cartridge inside newly opened sterile Links pouches, prior to placing in the Well Chamber to measure seed AKR prior to implant. This report includes data acquired in order to define corrective Shielding factors to account for seed to seed attenuation inside the cartridges. Additionally, as a Gold Standard, 5 linked seeds are made into a regularly spaced seedtrain, fitting into a standard strand holder within the Well Chamber, providing a Calibration route directly traceable to a National Dosimetry Standard. However, these seeds, since no longer sterile cannot be used in the clinical implant. Tolerance for the 5 seed assay is set at 3% and cartridge assay is currently within 5%.

Endoscopic retrograde cholangiopancreatography (ERCP) is an important technique to diagnose and treat the hepatobiliary system (i.e. liver, gallbladder and bile ducts). To minimise the radiation risk, doses must be monitored and compared with national or local diagnostic reference levels. This can be achieved through periodic dose audit.

A dose audit was carried out on patients undergoing ERCP procedures at Queen Alexandra Hospital between the period of 2010-2012. 41 diagnostic ERCP and 155 therapeutic ERCP were included in the study. Two indices, screening time and patient dose-area product (DAP), were compared against national data and a previous local dose audit. The screening time and mean patient DAP for the current dose audit were below the third quartile value derived from national data. However, the current patient DAP has increased compared to the previous local dose audit (2003-2004). Mean DAP for diagnostic ERCP has increased from 8.2 Gy.cm² to 10.2 Gy.cm² and 9.3 Gy.cm² to 15.9 Gy.cm² for therapeutic ERCP. This is despite the fact that mean screening time has decreased (diagnostic ERCP) or remains relatively unchanged (therapeutic ERCP).

Further investigation determined that the most likely cause of the increased patient DAP was x-ray equipment related. For the 2003-2004 dose audit, the ERCP procedures were carried out using the “Linear 5” curve on a Siemens Siremobil 2000 fluoroscopy unit, delivering a typical average skin absorbed dose rate of 13.5 mGy/min. In 2010-2011, these procedures were carried out using the “High Contrast 2” curve on a Siemens Arcadis Varic fluoroscopic unit, delivering a higher SADR of 18.9 mGy/min under the same measurement conditions.

Additionally, investigations were carried out to investigate the effect that other variables may have on patient DAP. These include the types of ERCP procedures, the complexity of the procedure, patient size and operators’ experience. The results of these investigations will be presented in the meeting.
Operator eye dose audit
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Elaine Holt, Cardiac Radiographer and RPS, UHSM Trust
Will Mairs, MPE, CMPE

Given the imminent reduction of the eye threshold dose level from 150mSv per year to 20 mSv per year, the Cardiology X-ray department at UHSM, conducted an audit to compare doses recorded at eye level with those recorded at collar level. The Objective of this audit was to “ascertain whether eye dosemeters worn at collar level will lead to greater compliance, thereby producing results which can be extrapolated accurately and consistently to give a realistic measurement of eye dose received by cardiologists working in cardiac catheter labs”

Currently, the cardiologists are asked to wear their dosemeters on a plastic headband just above their eyes. The Cardiologists have found these to be irritating and uncomfortable, and therefore ensuring compliance in wearing them is not always easy. If dosemeters are placed on personalized thyroid shields, compliance would always be 100% as no cardiologist undertakes a procedure without one. Can a factor therefore be established, that will give accurate and consistent measurements to enable the calculation of eye doses from those dosemeters worn at collar level?
This paper presents experience gained from a programme of radon monitoring of several hundred diverse properties within the Cornish NHS estate in on behalf of acute, primary care and mental health sector NHS organisations.

An overview of calculation of dose to workers and the public from exposure to radon is presented, both from ICRP60/65 and more recently ICRP103 and ICRP 2009 statement on radon, which has resulted in a ‘doubling’ of calculated doses (& may influence action levels in future legislation).

An approach to risk assessment & record keeping is presented; including examples for office and ward (high public occupancy) environments.

Practical aspects of RPA advice/estates management of a monitoring programme are discussed:
- The use of passive monitors & strategies for low/medium/high risk areas
- Seasonal correction factors
- The pros and cons of sump and positive pressure ventilation systems
- The use of electronic monitors to assess effectiveness of remediation methods
- Future monitoring and preventative maintenance considerations
The provision of radiation protection services to the London 2012 Olympic and Paralympic Games

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The provision of x-ray imaging facilities for the competitors in the London 2012 Games involved particular constraints with regard to radiation protection and compliance with the Ionising Radiations Regulations 1999 (IRR99) and the Ionising Radiation (Medical Exposures) Regulations. This paper concerns principally the former of these. Legally the radiation employer was The London Organising Committee for the Olympic and Paralympic Games (LOCOG).

The imaging facilities of the Games included the Athletes’ Village Polyclinic in the Olympic Park, Stratford equipped with multi-slice CT, a digital radiography (DR) room, mobile radiography and dental radiography (intra-oral and OPG). Additional dental x-ray facilities were installed at Egham (rowing competition) and Weymouth (sailing). For the football events hospitals local to the stadia were used. The radiographic and radiology staff were all volunteers released from their NHS employment. Additionally there was a veterinary clinic with x-ray facilities at Greenwich Park (equestrian competitions).

The radiological physics team from Imperial, under the auspices of the medical team, were appointed to provide the radiation protection advisory service to all but the football venues. Specific issues addressed arose from the design, installation and critical examination for the equipment, means of staff monitoring, the implementation of appropriate quality assurance procedures, multi-lingual signage, local rules and systems of work and investigations of staff exposure.

The presentation will illustrate some of the problems which arose from providing a service to a major international, complex and time-constrained event, and the solutions implemented with respect to IRR99 from the perspective of the RPA and the RPS.
Both Elekta and Varian have recently started to market linear accelerators which can be used in flattening filter free (FFF) mode. In FFF mode the instantaneous dose rate at the isocentre can be 6 times higher than on a standard machine. This leads to the question as to whether it is necessary to increase the shielding to accommodate this increased dose rate. Work published by Kry et al shows that following NCRP Report 151 guidance the shielding could actually be reduced if the accelerator were to be used mainly in FFF mode. This is because:

- The leakage radiation for a given dose to the isocentre is reduced
- Patient scatter fractions are reduced
- The beam is less penetrating in concrete (less so for Elekta)

NCRP 151 states that “The use of a measured instantaneous dose rate (IDR) with the accelerator operating at maximum output does not properly represent the true operating conditions and radiation environment of the facility.” Evidently if 7.5µSv/hr IDR is used as a design criterion, a different conclusion will be reached. It is therefore our contention that the guidance given in the flowcharts in the Medical and Dental Guidance notes provide a sensible rationale for approaching this issue.

New building options for Linear Accelerator bunkers will be described. A brief recap of conventional materials - concrete, steel and leadite blocks will be presented, along with information about currently available interlocking blocks of concrete and higher density materials used in the UK and elsewhere.

A reminder of attenuation characteristics of these materials will be presented.

A description of the proposed chapter structure and content of IPEM 75 2nd Edition will also be shown.

The fast changing technology and capabilities of modern Linear Accelerators have necessitated a change in approach for planning/demonstrating compliance with regulations.

A computational approach to this will be described.
Roundtable topic: Digital Dental QA: recommendations and problems

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Routine QC tests for analogue dental radiography are mostly concerned with film processing. New advice is required for those practices who have moved to CR or DR. Dental CR plates have short lifetimes, so image quality tests are crucial. We manufactured small test objects that can be used to assess the uniformity of the image. The test objects, made mainly of Perspex, include lead and air (hollow) sections to force the pixel values of the Perspex into the middle of the range. As with conventional radiography, dose can no longer be assessed through the optical density of the exposed film. Unlike conventional CR and DR, there do not appear to be any reliable exposure or detector dose indices.

Applying for RPA Body recognition – The Christie Experience
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Christie Medical Physics and Engineering (previously North Western Medical Physics) have, essentially, always acted as a corporate RPA due to our large customer base and number of physicists and technologists involved in providing RPA advice.

With the enactment of IRR99 came a requirement to get HSE recognition as an RPA Body. This required us to be able to prove that we were a legal entity, had enough accredited RPAs and had management systems to ensure that all advice was traceable to an accredited RPA. Much of this was relatively easy to prove as we already had an accredited quality management system covering our advice to diagnostic radiology, however work was needed to expand this to cover both radiotherapy and nuclear medicine.

Eventually, we gathered the evidence together and applied in March 2004. The HSE visited, raising concerns regarding impartiality and information for customers. Nevertheless we achieved recognition the following September. Since then we have been through one reapplication and intend to reapply next year.

Operating as an RPA body works for us. We believe that it provides necessary flexibility allowing us to use the most appropriate person for the task and to easily cover for each other. It also provides support to individual RPAs through working in the team and agreeing policy and methods together. The revised BSS allows for RPA bodies and we hope that this option continues within UK legislation.
Capability after limb loss: the challenges of measuring and mastering movement with an artificial limb

Thursday 26th September

A simple to implement and robust method of identifying ‘minimum toe clearance’ events during unilateral trans-tibial gait

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Alan De Asha & John Buckley

Background: Minimum toe clearance (MTC) is a critical gait event as it is when risk of tripping is highest. Lower-limb amputees have reduced MTC on the prosthetic- compared to intact-side, increased MTC variability on both sides and increased risk of tripping compared to the able-bodied. Assessment of MTC is thus clinically relevant. As toe-ground separation is minimal at toe-off automated event detection processes are difficult to implement. Synchronicity between peak swing-foot velocity (PFV) and MTC is widely reported but there are few empirical data supporting this contention; and there are no such studies involving lower-limb amputees. Our objective was, therefore, to determine the temporal relationship between PFV and MTC on the prosthetic and intact limbs in unilateral trans-tibial amputees (UTAs).

Methods: Kinematic data were collected at 100 Hz while ten UTAs walked overground at slow, customary and fast speeds. Timings of PFV and MTC and toe-ground clearances at each event, on intact- and prosthetic-sides, were compared using ‘Limits of Agreement’ analyses and repeated measures ANOVA respectively.

Results: 1200 PFV and MTC events were compared. PFV was consistently 0.014 ± 0.010 s after MTC on both limbs and across speeds (range 0.73 – 1.77 ms-1) and 95 % of PFV events occurred within 3 frames of MTC. There was no significant difference in values of toe-ground clearance between PFV and MTC events (p = 0.38). Toe-ground clearance was reduced on the prosthetic- compared to the intact-side (p < 0.001) and increased at higher walking speeds on the intact-side (p = 0.004) but not on the prosthetic-side.

Conclusions: PFV provides a robust, accurate and precise kinematic marker of MTC which is easy to implement in automated event detection processes. The absence of speed-related MTC increases on the prosthetic-side potentially increases UTAs trip risk at higher walking speeds.
A scientific basis for improving biomechanical function in amputees

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Dr Hannah Jarvis, Wing Commander Alex Bennett, Dr Martin Twiste, Professor Richard Baker

Background:
Amputees use more energy to walk a given distance than the able-bodied [1-4]. Despite considerable improvements in prosthesis design, especially within the last 10 years, there have only been minimal improvements in reducing the energy cost of walking in amputees [3]. A possible reason for this is that there has been little research conducted that has explicitly aimed to determine what factors are responsible for this increased energy cost.

Aim of investigation:
The aim of this study is to perform a biomechanically rigorous analysis of the factors influencing the mechanical work done throughout the gait cycle, with the aim of identifying which specific aspects of the gait pattern are responsible for the increased energy cost of walking.

Methods:
Data will be collected from 20 unilateral trans-femoral amputees, 10 bilateral trans-femoral amputees, and 10 able bodied individuals. Participants will walk for 12 minutes continuously within the gait laboratory, and three-dimensional kinematics and kinetics will be recorded (Vicon Motion Systems Ltd, Oxford, UK) using a full body multi-segment model. All kinematic and kinetic modelling will be performed in Visual 3D (C-Motion). Oxygen consumption will be collected simultaneously, and measured using Metamax 3B metabolic system (Cortex, Leipzig Germany). Estimates of mechanical work done will be compared between amputees and the able-bodied cohort on both individual and group levels. In addition, power flow analysis will be used to identify which joint moments are contributing to each significant segment energy change. Oxygen consumption measures will be used to evaluate how mechanical estimates of work compare with physiological estimates.

Results and Conclusions:
Understanding what particular features of the gait cycle are contributing to the increased energy cost of walking in amputees will enable a new generation of evidence based rehabilitation programmes, and prosthesis design to enhance the biomechanical performance of trans-femoral prostheses.

References:
Case study comparing gait of a bilateral trans-tibial amputee using two types of prostheses

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Rosie Richards, Matt Thornton, Roisin Delaney, Dr. Ian McCarthy

Introduction and method: This case study presents a gait analysis data from a bilateral trans-tibial amputee gait, comparing two types of ankle prosthesis; the hydraulically controlled echelon foot (EF) and the patient's regular fixed ankle prosthesis (FA). The joint kinematics, kinetics, temporal and spatial parameters were all evaluated. The patient was referred for gait analysis approximately 5 years after sustaining traumatic injury to her lower legs as a mature adult. Twelve typical trials were selected at self-selected walking speed wearing the FA and sixteen with EF. This resulted in 63 kinematic cycles (30 left, 33 right) cycles for the first condition and 78 (38 left, 40 right) cycles for the second condition, which were imported into Matlab for statistical analysis. Kinetic data consisted of 11 sets of force data (6 left, 5 right) for the first condition and 19 sets of force data (10 left, 9 right) for the second condition. An appropriately aged control group was selected, made up of 6 males and one female (mean age 33.5 ±3.5 and mean height 1.74 ±0.10m).

Results and discussions: The echelon prosthesis resulted in a significant improvement in the symmetry and normalisation of cycle timings. The use of the EF also enabled an increased in self-selected walking speed, approaching that of the control group. With the FA, the self-selected walking speed was only ¾ of the value of the control group. The overall increase in speed using the EF was 0.21m/s between the two trial conditions due to an increased cadence rather than change in stride length.

The mean sagittal position of the ankle during the EF trial condition was significantly more dorsiflexed than during the FA throughout the cycle on the right side and during the double support periods and swing period on the left side. In addition there was a significant difference in the ankle position in either type of prosthesis compared to the control group; in particular the prostheses had a restricted range of movement during the pre-swing and swing periods. The EF also facilitated normal movement at the knee, in particular alleviating hyper-extension during single support phase.

In comparison with the control group, the medial ground reaction force was significantly increased with both types of prosthesis, with a larger step width compared to the controls. This may be necessary to for increased stability or balance. Use of the EF did not significantly affect the medial force. The peak propulsive (anterior) ground reaction force was significantly lower than the control group but was largely unaffected by the echelon feet.

The peak power generation by either type of prosthesis during push off was significantly lower than that of the control group, typically less than half the power. This is likely to be as a result of the reduced angular velocity compared to the controls during the third rocker; the moments about the joint are actually slightly higher than in the controls. The echelon foot afforded a small but statistically significant increase in peak power generation during push off.

Conclusions: This single case study suggests that the echelon foot improves function both at the ankle and more proximally, enabling a more typical gait pattern. The improvements in the gait pattern translate into the functional benefit of increased speed of walking. Changes were clearly shown in the kinematics, with more subtle changes in the kinetics. Over a longer-term, the effect of the prosthesis on the more proximal joints, particularly at the knee, may be important in reducing the likelihood of orthopaedic disorders for example osteoarthritis.
Changes in prosthetic foot deflection and lever arm due to changes in external rotation angle

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Introduction:
Despite the importance of aligning lower limb prostheses in all planes, the literature mainly reports on the sagittal plane1, whereby the transverse plane has received far less attention and particularly the external rotation angle (ERA) of the prosthetic foot. This angle is defined by the line of walking progression in relation to the foot axis (extending from a point between the distal ends of the second and third toe to the centre of the heel)2. An approximately 7° ERA is used in common clinical practice where the medial border of the prosthetic foot is aligned in parallel with the line of walking progression, although this can vary by up to 12°3. Although amputees are able to accommodate a range of ERAs, gait changes can occur due to deviations from standard alignment, and this is not surprising considering that the ERA determines the sagittal plane foot lever arm. As existing studies on this were largely inconclusive, there is hence a need for further exploration of the effect that ERAs have on amputee gait. Therefore, this study measured changes in prosthetic foot deflection and lever arm in response to changes in the ERA during simulated stance.

Methods:
Measurements were taken independent of the amputee to avoid compensatory gait mechanisms. Using 3 different prosthetic feet, ERAs were adjusted to 0°, 5°, 7°, and 12°, as these are within the reported range of ERAs for clinical alignment2,3. A test-rig and a motion capture system were used to obtain 5 prosthetic foot roll-over shapes from a pylon-based reference frame for each ERA.

The prosthetic foot lever arm was calculated from the ‘Effective Foot Length Ratio’ (EFLR)4, defined as the ratio of the sagittal plane length from the posterior end of the foot to the anterior end of the roll-over shape in relation to the length of the foot. Statistics were used to test for data normality and within-foot differences.

The prosthetic foot deflection was determined by a) normalising each roll-over shape over 100 points and then averaging the 5 roll-over shapes for each ERA; b) calculating the distance between each of the 100 points of the average roll-over shape (from a) of each pair of ERAs; and c) averaging (AveD) all 100 distances (from b) for each pair of ERAs using sagittal plane 2D coordinates from the pylon-based reference frame.

Results and Conclusions:
The AveD was similar for all feet and ERAs and reached a maximum of only 3mm. In turn, the EFLR increased with increasing the ERA up to 5° (presumably because the big toe became closer aligned with the line of walking progression) and then decreased again with further ERA increases up to 12°, but the maximum length difference between roll-over shapes was only 2mm. Therefore, ERA increases up to 12° had little effect on prosthetic foot deflection and lever arm. Further research is needed to observe the effects that changes in ERA have during in-vivo tests.

References:
A biofeedback gait re-training system for trans-femoral amputees

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Following discharge amputees do not always receive regular reviews by physiotherapists, and may adopt a variety of habitual gait patterns that can lead to back pain. The increase in transverse rotation of the pelvis in trans-femoral amputees, as produced by circumduction, is a contributing factor to lower back pain (Morgenroth et al., 2010). Real-time biofeedback of kinematic data to amputees may help address inappropriate habitual gait patterns. Recently there has been renewed interest in the application of biofeedback for gait re-education (Lunenburger et al. 2007). Such feedback could also help therapists convey information to patients regarding kinematic alterations during hands-on physiotherapy in a rehabilitation gym.

Aims

This paper summarises the development of a real-time biofeedback training system to assist in the reduction of habitual circumduction and abduction gait patterns seen in trans-femoral amputees.

Biofeedback Training System

The system (Figure 1) uses a passive infra-red motion capture system (ProReflex, Qualysis, Sweden) to track lower limb kinematics whilst the amputee walks on a treadmill. Software was written using LabVIEW (National Instruments, UK) to calculate and compare the hip joint angles against a reference data set in real-time. The extent of gait deviation is determined from the combined coronal and sagittal hip joint angles and guides the delivery of an electro-tactile stimulus around the surface of the stump.

A multi-channel stimulator was developed which produces an electro-tactile sensation through an array of eight annular skin surface electrodes. Each electrode pair contains an active conductor surrounded by a single reference. The conductors were etched from a flexible polyimide printed circuit. A hydrogel formed a self-adhesive skin-electrode interface. Further details of the training system can be found in Webb (2013).

The stimulator provides control of the waveform pulse-width, frequency and amplitude. To determine which parameters produce a comfortable sensation on the thigh surface, under different neuromuscular conditions, the sensory thresholds and stimulus discrimination abilities of thirteen non-amputees and four trans-femoral amputees were investigated. Subjects were recruited from the University of Surrey and Queen Mary’s Hospital (Roehampton) respectively. The four amputees then went on to test the usability of the training system. The studies received favourable consideration from the NRES London-Surrey Borders and University of Surrey Research Ethics Committees.

Figure 1 Biofeedback Training System Overview
Results
Sensation threshold levels and the ability to discriminate stimuli were found to be comparable between the amputee and non-amputee groups. The amputees reported positively on the use of the system. They were able to perceive and understand the feedback stimuli, relate the information to their movement, and in some cases make positive changes to their gait.

Discussion
This work has the potential to become integrated into prosthetic components, and can be adapted for use with a broader range of patient groups with upper and lower limb movement disorders. The analysis software has the potential to be further developed to provide real-time interpretation of gait patterns.

Acknowledgements
The authors wish to express their thanks to staff from the Douglas Bader Rehabilitation Centre, Queen Mary's Hospital.

References
Personal exposure to static and time-varying magnetic fields during MRI procedures in clinical practice in the UK

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Background and aims
An introduction to this study was presented at the IPEM MR Safety Update in 2011. This presentation will show the progress made in the study since the 2011 meeting and provide an overview of preliminary findings.

Medical diagnosis using Magnetic Resonance Imaging (MRI) is the main source of exposure to high static magnetic fields in humans. Extensive safety protocols have been developed to ensure the safety of patients and personnel. However, personal exposure levels of UK healthcare staff routinely working with MRI systems are currently unknown.

The aims of this study are: to measure personal exposure levels of personnel routinely working with MRI in UK hospitals; to determine potential differences between jobs and between individuals with the same job; to identify factors that may increase or decrease personal exposure.

Methods
Eleven hospitals across the UK agreed to participate in the study. All members of staff routinely working with MRI were invited to participate in the study. In addition, 1-2 unexposed controls were recruited in each hospital. Personal exposure was measured during multiple work shifts using a novel magnetic field dosimeter, clipped to a waist belt. The dosimeter simultaneously records the static magnetic field (Bx,y,z) and temporal changes in the static magnetic field (dBx,y,z/dt) in all three orthogonal directions (x,y,z) with a temporal resolution of 50Hz and 8kHz. Prior to the exposure measurements participants completed a baseline questionnaire. On the day of the measurements, participants also completed a work diary, documenting procedures and the time they spent in the scanner room.

Results
Data collection is currently ongoing. To date 83 participants have been recruited and 117 measurements have been collected. The majority of participants were radiographers (75%), followed by healthcare assistants/radiography helpers (14%), anaesthetists (8%) and operating department practitioners (3%). The average static field exposure of exposed staff (mean:18.1mT, SD:±10.1mT) was approximately twice that of unexposed controls (mean:9.3mT, SD:±2.3mT). However, exposure levels varied between job category and between individuals with the same job, with radiographers, radiography helpers and anaesthetists experiencing the highest exposure levels.

Conclusions
Preliminary results do indicate differences in exposure levels between job categories. However, variability between individuals with the same job also appears to be high. Further data collection and analyses, may provide insight into specific factors increasing or decreasing exposure levels.
A preview of the new MHRA MRI guidelines

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I will be providing an update on:

Progress of the 4rd edition of the MHRA MR safety guidance
Progress of the revision of the Medical Device Directive
Review of recent MR related incidents
Update on NSF & Gadolinium containing Contrast agents

MHRA is a centre of the Medicines and Healthcare Products Regulatory Agency
The Physical Agents (EMF) Directive: The End of the Road at Last?

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Members of the MRI community will be aware of the problems posed by the European Union (EU) Physical Agents (Electromagnetic Fields) Directive (2004/40/EU) [1, 2], and of the campaign to mitigate its impact [3, 4]. The aim of this presentation is to bring colleagues up to date with recent developments, and to explain what remains to be done as the issue finally draws to a conclusion.

The 2004 directive was due to be implemented by 30th April 2008. In 2007, following intense lobbying, the European Commission announced postponement of this deadline by four years. Then, in June 2011, the Commission proposed a replacement directive, in which EMF exposure limits would not apply to MRI workers and safe working practices would instead be developed to ensure health and safety in MRI. This proposal was opposed by influential EU member state governments, and in April 2012 a further implementation delay of 18 months was announced.

Following another year of negotiations, a new EMF directive (2013/35/EU) was adopted by the EU on 11th June 2013 [5]. Article 17 of this directive contains words that are welcomed by all of us involved in this long campaign: ‘Directive 2004/40/EC is repealed from 29 June 2013’.

Directive 2013/35/EU retains the exemption (or derogation) from EMF exposure limits that was a key feature of the 2011 proposal. However, there is considerable uncertainty regarding the scope and conditions of this derogation, reflecting an attempt to reconcile the contrasting positions held by member states. This may result in different legal interpretations in different European countries.

The deadline for implementation of the new directive is 1st July 2016. Before then, the European Commission will issue a non-binding practical guide, which may help to resolve the ambiguities in the directive. National authorities are also carrying out their own preparations, and in the UK the Health and Safety Executive is working closely with the MRI community to develop guidance on implementation. For further details of the directive and next steps, see [6].

The Radiological Sciences Unit of the Imperial College Healthcare NHS Trust London provided the MR physics and safety support to the London 2012 Olympic and Paralympic Games. This unique piece of work involved liaison with LOCOG (The London Organising Committee for the Olympic Games), sponsors (General Electric), the voluntary radiology team. A 1.5T and 3T wide bore MR systems were commissioned at the Stratford Polyclinic, with acceptance testing, fringe field surveys, and the development of suitable policies, procedures and local rules. Specific issues encountered included the choice of equipment, the siting of the scanners, shielding and fringe field and procedures for implants. From a population of 10,566 athletes, a total of 1,079 MRI scans were performed during the games, without incident.
Guidelines currently in place guard patients against excessive radio frequency (RF)-induced tissue heating when undergoing a magnetic resonance imaging (MRI) scan [1]. The presence of metallic implants inside the body can locally enhance RF absorption, and has the potential of causing guideline maximum temperatures to be exceeded. This can cause discomfort, pain or even tissue necrosis in extreme cases.

Implant testing for compatibility with the RF fields typically found in an MRI scanner is done in line with ASTM standard F2182-’11 [2]. The implant under test is positioned inside a phantom with similar properties to the human body, and the phantom is made to undergo a typical MRI scan. The temperature in the vicinity of the implant is monitored throughout the scan. The implant is then removed and the phantom is left to return to room temperature before the scan is repeated to determine the temperature rise in the absence of the implant. The ratio of the two measurements gives an estimate of the temperature rise amplification caused by the presence of the implant.

A facility has been established at the UK’s National Physical Laboratory (NPL) to recreate the RF fields typically found inside a 1.5 T MRI scanner, allowing implants to be tested in a laboratory environment to ASTM standards. The facility, measurement procedures and associated uncertainty budgets will be described, along with the results of a typical set of measurements performed on an orthopaedic implant. The system has been benchmarked against a Philips Achieva 1.5 T scanner, and these results shall also be presented.

When combined with other measurements such as the magnetically induced displacement force and torque, the implant can be labelled MR safe, MR conditional or MR unsafe [3]. The marking is typically entered into a public database for easy consultation by the radiographer [4].

For implants labelled MR conditional, the limitations of the measurement procedure described are to be well understood for the results to be useful to the radiographer. The electrical and thermal properties of the human body vary significantly and are likely to be different to those of the phantom, causing discrepancies that need to be accounted for. To account for these variations, computational models can be used to determine the temperature rise induced by the MRI coil in the human body in the absence of the implant before applying the measured amplification ratio to determine the temperature rise in the presence of the implant.

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REFERENCES


Background Focused ultrasound surgery (FUS) is proposed as a possible non-invasive therapy option for targeted malignancy and also has links to ultrasound-mediated targeted drug delivery. With magnetic resonance imaging as guidance, MRI-guided focused ultrasound surgery (MRgFUS) requires the ultrasound transducers to be positioned within the MRI system. In this case, the compatibility of the ultrasound sources with MR environment is of particular interest.

Material and Methods Five therapeutic ultrasound transducers were designed and fabricated in-house with exclusively non-magnetic material; the first transducer has a single element, whilst the other four have 96 individual elements arranged in a geodesic structure. The single element transducer was tested in both 1.5T GE HDx and 3T Siemens MRI systems. The artifacts in MR images caused by ultrasound were investigated by activating the transducer with external electronics. The related temperature rise at the focus of this transducer was analyzed as well; using an ExAblate2100 conformal bone system (InSightec Ltd, Haifa, Israel) integrated in 1.5T MRI, and post-proton resonance frequency (PRF) calculation in 3T MRI. The passive compatibilities of the four geodesic arrays were tested in 3T MRI guiding by ASTM standard F2119. Three orientations were scanned, with each orientation having two sets of images, using both readout and phase-encode directions.

Results and Conclusion With effort to avoid radio frequency interference, the image quality was significantly improved with shielding and filtering applied. The thermal performance of a single element transducer was measured at several electrical input levels, and the temperature rise evaluation of up to 27°C was observed via the ExAblate platform and 21°C from post-calculation 3T MRI. Artifacts were observed in all images for passive ultrasound arrays near electrical connections. However no severe effects were observed in identifying the transducer location and shape, and no severe effects to the focal area within the phantom area of interest for FUS sonication.
Defined FIXED PARAMETER OPTION BASIC (FPO:B) for MR conditional scanning: A method of scanning MR conditional implants safely
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Proposal to introduce the Fixed Parameter Option:Basic (FPO:B) for MR scanners to enable the scanning of patients with MR Conditional implants. FPO:B defines a set of gradient and RF field output limits, within normal and first level mode, that: 1) provide exposure limits which MR scanners adhere to, 2) provide 1.5T MR imaging capabilities similar to present Normal Mode operational limits, and 3) in conjunction with IEC TS 10974 facilitates the testing to label AIMDs MR Conditional within the FPO:B limits.

Text courtesy of Michael Steckner, IEC
MR interactions clarified as rules of thumb for daily use in practice of implants and devices used in MRI
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Acknowledgement: We thank Dr. Harald Kugel, Dr. Hans Engels and Dr. Martin Muehlenweg as well as Prof. Dr. Andreas Melzer (Chair, German VDE technical committee ‘MR Technique in Medicine’ for commenting and reviewing this article

Background
MR interactions which have been identified in the past years of standardization and guidance documents ([1],[2]) show that there is a certain complexity in order to clarify hazards exhibited if a device or item enters into the MR environment. The complexity of clarification is simpler with interactions caused by the static magnetic field, but it increases significantly with the increasing number of different parameters describing the switched gradient magnetic field and the electromagnetic radio frequency (RF) field. For MR users it is, therefore, difficult to assess whether it is safe or conditionally safe to scan patients with medical devices, if the MR user in charge does not have a professional background in physics or electromagnetics.

Subject
For maintaining daily a high-performance workflow, however, clarification of MR safety and compatibility is mandatory in a reliable and timely manner. The first choice for professionally performing the clarification of implants and other devices for use in the MR environment is reading the MR labeling provided by the medical device manufacturer. However, with this MR labeling still certain difficulties remain as not all labeling is complete and comprehensive according to the up-to-date technical status of ASTM F2503 and the FDA guidance. In order to provide the MR user with additional information about dimensions and directions of possible interactions with MR, a rule of thumb system is provided here to assist basically if clarifying (risk assessment) issues using MR labeling information. This system of rules cannot replace the official MR labeling provided by a device manufacturer. It should only be used as background in addition to the original MR labeling information. Using the rule of thumb system given below without referring to existing MR labeling would constitute an off-label use of the MR system.

The following MR interactions are discussed:
1. a) Displacement force (static) is expected to be lower, if materials are diamagnetic, paramagnetic and low ferromagnetic quality; if MR magnets have a smaller static magnetic field B0 (magnetic saturation) or smaller static magnetic field gradient of the fringe field 2. a) Torque (static) is expected to be lower, if materials are less magnetic (see 1. a); if static magnetic fields B0 are small (see 1. a)); if the geometric dimensions of the device are smaller; if devices are more flexible; 1. b) Force (dynamic), and b) Torque (dynamic) is expected to be lower, if the material conductivity, the effective area of induction, the speed of the movement as well as the magnitude of the static magnetic field is lower; effect is possible for conductive devices 3. a) Voltages, gradient-induced, which can lead to, 4 a) Heating, gradient-induced, and, 5 Vibration, gradient-induced: Switched gradient field interactions are most likely decreased, if conductive devices are kept out of the high dB/dt exposure area; if these are short and have a small cross section; if dB/dt related sequence parameters, e.g. gradient modes are adjusted to low output, (“whisper gradients”); if the field of view (FoV) is enlarged with constant or a lower matrix resolution
3. b) Voltage, RF-induced, which can lead to, 4 b) Heating, RF induced: RF interactions are most likely decreased, if electrically conductive devices are kept out of the RF transmit coil; if oriented orthogonal to the electric (E)-field; if are short relative to the half RF wavelength within the tissue; if SAR parameters are adjusted appropriately: TR is increased, Flip angles low, B1 and SAR modes are adjusted to low output, Number of RF pulses (Echo train length) low, Distance of echo pulses (Echo spacing) increased

6. Malfunction of the device is most likely decreased, if mechanical functions do use non- or low-magnetic components; if electrically conductive devices are kept out of the high dB/dt and RF exposure area, are short (relative to the half RF wavelength) and have a small cross section, are passive or non-electronic devices or do not use pressure sensors (interaction with acoustic noise likely)

7. Artifacts are most likely decreased, if the strength B0 is low; if materials are non- or low-magnetic; if plastic materials are free from protons (possible generation of proton signal as signal spot); if the low-magnetic component’s long axis is aligned parallel to B0 instead of orthogonal; if spin echo based sequences are used instead of gradient echo based sequences; if time of echo (TE) is short; if the flip angle or strength of B1 is low; if electrically conductive devices: are kept out of the high dB/dt and RF exposure area, have a small cross section and are short (relative to the half RF wavelength in tissue) or have a low conductivity of the device’s material, e.g. plastics versus metals, but also amongst metals: e.g. titanium versus gold

Summary
A compact rule of thumb system is shown, which should support the MR user basically if clarifying issues using MR labeling information. The official MR labeling is important and still necessary, provided by a device manufacturer. Using the rule of thumb system given above without referring to existing MR labeling would constitute an off-label use of the MR system.

References
What do we do when implant MRI safety guidance is unavailable, incomplete, or inappropriate?

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Among the responsibilities of the MR Safety Expert is the provision of scientific advice supporting decisions regarding the safety of scanning patients with passive or active implantable devices. Decisions as to whether to scan in a specific case should ideally be taken in the context of a multi-disciplinary team including Clinical Scientists, MR radiographers and radiologists, with a clearly identified individual assuming clinical responsibility for the safety of the patient.

Such decisions involve risks assessments, with identification of a hazard, assessment of hazard severity, and the likelihood of resulting injury. Steps may then be taken to mitigate the hazard, reducing the risk to an acceptable level, which we would expect to be close to zero for diagnostic MRI. Assessment of injury likelihood has various aspects, including statistical probability of a stochastic event (e.g. DNA damage, physical accidents), and uncertainty arising from incomplete knowledge of the nature and magnitude of electromagnetic interactions of a specific configuration. This latter aspect is a common concern of the MRSE.

Often safety decisions are straightforward where clear guidance is available, either generic advice (MHRA, literature, mrisafety.com) or manufacturers’ product label instructions in the case of FDA-approved or CE marked medical devices. Difficulties arise when specific device information is not available, is incomplete, or appears inappropriate. While the most straightforward option is to not scan in such situations, such a decision may deprive patients of access to vital diagnostic or therapeutic procedures.

As a case study I will describe the history of the Deep Brain Stimulation (DBS) electrode implantation MRI service at the National Hospital, where over a period of more than 9 years we have safely scanned more than 300 cases with in situ DBS instrumentation both within, and latterly outside the device manufacturers’ product label guidance. A combination of multi-disciplinary scientific and clinical expertise, experienced specialist radiography staff, local experimental safety assessment and close adherence to a well-defined safe-scanning protocol have underpinned the safe provision of this service.

References
The MRSIG has recognised a need for a register of MR safety experts / advisors since 2001. Since then various proposals have been looked at including a voluntary register. In 2010 a working party was set up to look at the issue. A questionnaire was distributed to a selection of MR units to ascertain current provision of MR safety advice. A decision was also made to produce a policy statement on the provision of scientific safety advice which would then be followed at a later date by more specific details on how registration would work in practice. The policy statement was published in October 2013 and is available through the IPEM website. The policy statement recommends that all organisations that operate MR equipment for the imaging of human subjects should engage the services of an MR safety expert and defines typical roles and responsibilities and the knowledge and competencies that such a person should possess. It is made clear in the statement that such a person should have a thorough and detailed understanding of MR physics and should understand the context in which the advice is sought and given. It is also recognised that MR safety requires a multidisciplinary approach and that the MR safety expert is part of a team that includes MR radiographers and radiologists. Finally, the policy statement recommends that a register of MR safety experts is established.
A Systematic Approach to MR Safety Labelling of Ancillary Equipment in the MR Controlled Area

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The Medicines and Healthcare products Regulatory Agency (MHRA) recommends that all equipment that may be taken into the MR Controlled Area is clearly labelled using ASTM (American Society for Testing and Materials) International standard F2503-05. This stipulates that equipment is labelled as one of the following:

MR Safe an item which poses no known hazards in all MR environments

MR Unsafe an item which is known to pose hazards in all MR environments

MR conditional an item which has been demonstrated to pose no known hazards in a specified MR environment with specified conditions of use. Field conditions that define the specified MR environment include field strength, spatial gradient, dB/dt (time rate of change of the magnetic field), radio frequency (RF) fields, and specific absorption rate (SAR). Additional conditions, including specific configurations of the item, may be required.

A systematic review of ancillary equipment was carried out across 8 MR imaging facilities across Lothian and Fife. The safety status of each item of ancillary equipment was reviewed using a locally produced standard operating procedure. Each item of equipment was labelled appropriately. A photographic record was produced for each item of equipment and embedded into the database. The MR Responsible person is provided with a copy of the database for their records; the contents of which are reviewed together with the MR Safety advisor at an annual MR safety review. The database is amended as items of equipment are discarded or purchased for the MR controlled area. MR Unsafe labels are issued to MR Responsible Person for attaching to equipment as they see fit. MR Safe and Conditional labels can only be attached to equipment by Medical Physics personnel following appropriate assessment.

The work highlighted the significant number of items of ancillary equipment that are used in MRI departments, including the large proportion of equipment that is MR conditional or MR unsafe. The work has helped reduce the risk of an adverse incident in each MR facility through appropriate labelling of equipment and by identifying items that can be replaced by more suitable MR safe/ MR conditional equipment, or removed from the controlled area altogether. Results to be presented.
POSTER 2
An Audit of Temperature Maintenance During Paediatric MRI Under General Anaesthesia
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Introduction
Patients undergoing general anaesthesia (GA) often become hypothermic (temperature < 36°C) whereas patients undergoing MRI scans may increase their core body temperature due to absorption of radiofrequency energy1. There is some evidence that patients having MRI scans under GA have a decrease in core temperature2. Guidelines recommend that patient temperature is monitored every 30 minutes during general anaesthesia3. We decided to audit temperature maintenance in children having MRI scans under GA and subsequently re-audited this patient group after altering how we passively insulated them from the cooling effects of the fan in the MRI bore, which cannot be turned off (Philips Achieva 1.5T). Children were passively insulated with a muffler, which is designed to reduce noise exposure for infants undergoing MR scans.

Method
We conducted a prospective audit of paediatric patients (aged <11 years) attending for outpatient diagnostic MRI scans. The aim of the audit was to ensure that normothermia was maintained in paediatric patients having MRI scans under GA. The criterion was that core temperature should be maintained between 36 and 38°C throughout the procedure and we set the standard at 100% compliance. Patient temperature post GA induction and post MRI scan was measured using an axillary temperature probe, and recorded. The weight of the patient, duration of the MRI scan and attempts to conserve body heat were also recorded. The same data was recorded for both the initial audit and the re-audit.

Results
For the initial audit, data was collected for 20 patients from September to November 2012. The ambient temperature in the MRI suite was 22°C. During the re-audit, data was collected for 14 patients between April and July 2013.

<table>
<thead>
<tr>
<th></th>
<th>Initial Audit</th>
<th>Re-Audit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Age Range</td>
<td>5 months – 11 years</td>
<td>3 months – 6 years</td>
</tr>
<tr>
<td>Weight Range (kg)</td>
<td>4-31</td>
<td>6-23</td>
</tr>
<tr>
<td>Temperature post induction (n;%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36≤ToC&lt;38</td>
<td>19 (95%)</td>
<td>14 (100%)</td>
</tr>
<tr>
<td>35≤ToC&lt;38</td>
<td>1 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>Temperature at completion of scan (n;%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36≤ToC&lt;38</td>
<td>9 (45%)</td>
<td>11 (79%)</td>
</tr>
<tr>
<td>35≤ToC&lt;36</td>
<td>9 (45%)</td>
<td>3 (21%)</td>
</tr>
<tr>
<td>34≤ToC&lt;35</td>
<td>2 (10%)</td>
<td>0</td>
</tr>
<tr>
<td>Covering:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>Blanket</td>
<td>19 (95%)</td>
<td>3 (21%)</td>
</tr>
<tr>
<td>Blanket &amp; Muffler</td>
<td></td>
<td>11 (79%)</td>
</tr>
</tbody>
</table>

Figure 1: Results of the initial audit and re-audit
Due to the nature of some scans, it was not possible to cover 3 of the children in the re-audit with a muffler. Of the 3 children who were mildly hypothermic at completion of the MR scan, one was only covered by a blanket.

Discussion
Maintenance of normothermia is of particular importance in unwell patients. The heat loss associated with general anaesthesia and the cooling effects of the fan inside the scanner can cause hypothermia in children having MR scans under GA. Patient temperature should be monitored for scans under GA taking longer than 30 minutes. Unfortunately the fan inside the bore of our scanner cannot be turned off as this is a built-in safety feature. Children should be passively insulated with a blanket and, if possible, a muffler, as our audit has shown this may limit the number of children developing hypothermia. Children who become hypothermic should be actively warmed in recovery and normothermic prior to discharge.

References
Implanted medical devices (IMDs) treat and monitor a myriad of physical conditions within the patient and are an indispensible component of modern medicine. The presence of IMDs is a very well known safety concern for MRI, as many can interact with the various electromagnetic fields associated with MRI, potentially causing harm or death. Hence, there is an involved screening process for MRI.

For other imaging modalities and therapeutics, interactions with IMDs are less well known and publicised. The authors present various examples of implications, contraindications and conditions associated with IMDs and Radiotherapy, X-ray, CT, Ultrasound, Nuclear Medicine, Microwave and RF ablation, TENS, ECG, Electrocautery, Diathermy, Electrolysis and certain Psychotherapeutics among others. Interactions with other IMDs are also considered.

The potential arises that if a patient is denied MRI the next best option may not also be available. Raising of awareness in the MRI community of these effects is important and we are not alone in having safety concerns for a patient that presents with an IMD.
Safety is paramount in a clinical MRI setting and as such, thorough safety checks are incorporated into routine procedures, following MHRA guidelines.

Guernsey, being an island, faces certain difficulties in terms of continuity of patient care. Challenges encountered by MRI staff in Guernsey include limited information on patient history (e.g., previous trauma, surgery or implants) due to a multitude of health institutions being involved in a single episode of patient care. These can include general practices; the local specialist centre; the island hospital; as well as mainland UK hospitals and clinics, which all may have individual patient records. This results in multiple locations of patient case notes with no centralised or electronic method of viewing. Patients are often unaware of the exact nature implanted devices or even the type of surgery they have undergone which also makes determining safety status difficult.

Following an incident involving a ferromagnetic object being taken into the MR system room, several recommendations were made to increase safety levels within the department. These recommendations included implementation of a ferromagnetic detection system (FMDS) to provide a tool to aid in safety screening prior to permitting patients and staff entering the MR system room. Our objectives were to prevent a similar unexpected adverse incident and to decrease the risk from unknown or forgotten items or implants, whilst taking into consideration available space and workflow resources.

A ferromagnetic detection system (Ferroguard, Metrasens Ltd) was obtained in consideration of our objectives. Limitations of space and layout in the department meant special consideration had to be given to the choice and method of FMDS in order to allow patient screening as well as entryway control using just one pair of detector pillars.

An initial study was undertaken to determine the efficacy of this system that resulted in identification of various items by the FMDS even after routine safety checks and screening procedures had been performed. This most commonly when patients had forgotten about and not removed ferromagnetic items (e.g. dental plates, clothing, therapeutic magnets), demonstrating the importance of this additional safety procedure. Following these encouraging results, further research is planned to continue evaluating the clinical use of a ferromagnetic detection system.
POSTER 6
Measuring the Spatial Magnetic Field Gradients within a Scanner Bore
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1Neuroimaging, Maudsley Hospital, London, UK, 2Centre for Neuroimaging Sciences, King’s College London, London, UK, 3Neuroradiology, King’s College Hospital, London, UK, 4Medical Engineering and Physics, King’s College Hospital, London, UK, 5Centre for MR Research, University Children’s Hospital, Zurich, Switzerland

Introduction: Although the use of magnetic resonance as a diagnostic imaging tool has been in existence for many years, there is now a growing need for manufacturers to produce medical implants and devices which can be classified as MR conditional, if not MR safe. The usual conditions specified by the manufacturer in addition to the static magnetic field strength or the operating mode in which to minimize specific absorption rate, is the maximum spatial magnetic field gradient (MFG). This spatial MFG is a measurement of the difference in magnetic field strength between two known points, and is expressed in Gauss per centimetre (G/cm) or Tesla per metre (T/m). The purpose of this project was to determine the spatial magnetic field gradients present within the patient accessible areas of our MR scanners, and compare our results with those given by the manufacturer.

Methods: Measurements were obtained from two GE Signa TwinSpeed HD.x (1.5T and 3.0T) MRI scanners, and two GE Discovery MR750 3.0T scanners, using a 2-dimensional template made out of sturdy cardboard to represent the internal axial dimensions of each scanner bore. A 10cm vertically and horizontally-lined grid was marked on the template with Y incrementing anteriorly from zero at the bottom, X incrementing laterally from zero at the centre, and with the laser lights corresponding to the intersecting point X=0, Y=0, Z=0. The strength of the magnetic field at each node point on the template was measured in KGauss using a THM1176 Hall probe commencing with the position Z=0. These measurements were repeated at 10cm increments along the Z plane for the length of the scanner bore. Separate gradient calculations were made for each orthogonal direction by subtracting the previous field strength measurement from the next adjacent one. Finally, the vector sum of the 3 gradients was obtained.

Results: The strongest gradients (Gauss/cm) for all scanners were found along the Z direction, with gradients in the X & Y directions comparatively negligible, and with the vector sum values approximating the Z gradients. Gradients higher than 500 Gauss/cm for the 3 Tesla scanners and 350 Gauss/cm for the 1.5T scanner, where found around the perimeter of the bore, and within 20cm and between 10 and 20cm of the bore respectively. The maximum gradient value for each 3Tesla scanner was over 700 Gauss/cm, whereas the 1.5Tesla scanner had a maximum gradient value of just over 400 Gauss/cm. The 1.5T scanner and one of the 3T MR750 scanners each had their maximum gradient value located at the left edge of the bore 10cm above the couch, whereas the remaining two 3 Tesla scanners were found to have their maximum gradient value at the top centre of the bore ~40cm above the couch (Figure 1a-d).

Discussion: Although the MRI scanner manufacturer expressed all their maximum spatial magnetic field data in cylindrical coordinates from the magnet isocentre, the location of these values corresponds to being near the bore entrance. Also, their values which are located at some distance within the bore casing are approximately 1.5 and 2 times that of our local calculations (1.5T and 3Ts respectively). It is then reasonable to believe then that had the manufacturer’s measurements been made within the patient accessible area, our measurements would be more comparable.
Figure 1: Spatial magnetic field gradients depicted on template diagram for MRI scanners a) 1.5T HDx, b) 3T HDx, c) 3T MR750 (1), d) 3T MR750 (2), where red numbers are the maximum.

References:
The scanning of pregnant patients and other issues around pregnancy and breastfeeding in MRI have long been an important topic from the point of view of MR safety. It has been hypothesized that the foetus may be adversely affected by possible bioeffects associated with the static magnetic field, heating induced by the RF field or excessive acoustic noise. Additional concerns have been raised around the transmission of potentially toxic gadolinium-based contrast agents transplacentally or via lactation.

Relatively few clinical studies using human subjects have been performed in this field, and risks are difficult to fully assess due to the range of interacting factors at play. As a result, recommendations on best practice from a number of national and international sources have adopted varying degrees of caution, have changed notably over time, and have occasionally been significantly out of step with each other.

This poster summarizes concerns relating to entry into the MR Environment, scanning and administration of contrast to pregnant or breastfeeding individuals, with specific reference to current and past recommendations from a range of sources.

Pdf copy of poster available on request from aaron.mccann@belfasttrust.hscni.net
Safety considerations for MR scanning of patients injected with a PET radioisotope: Paediatric patients undergoing 18F-DOPA PETMR procedure for investigating hyperinsulinomas

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The current imaging pathway for these patients usually involves PET/CT. However, with the introduction of PET/MR as a clinical imaging tool at the new UCH Macmillan Cancer Centre, in the spring of last year, there is an opportunity to entirely remove the radiation burden due to X-ray CT exposure for paediatric patients. The mMR Biograph (Siemens, Erlangen, Germany) combining a 3T Verio magnet with a 25.6cm FoV customised PET detector ring at the isocentre allows simultaneous imaging of PET and MRI. To date 12 patients aged 0-8 yrs have been imaged. The combination of high magnetic field strength, radioisotope management and paediatric patients produces a trifactor of highly sensitive parameters that need to be managed with due care and attention by the unit staff. We present here a basic pathway highlighting the extra consideration to safety and additional training required by this situation.

Patient and carer safety: In order to facilitate ordering and utilisation of the radiopharmaceutical a thorough screening of each patient for any MR contraindications is essential at prior to the booking of the examination. In addition, the patient will always be accompanied by their parents and at least one member of the care team from the neighbouring children’s hospital and are required/wish to be in the scanning room during acquisition. Therefore, in the first instance a nurse specialist from the Great Ormond Street Hospital (GOSH), having been trained in MR safety will provisionally complete MR screening for the child and the family and contact the PET/MR department with any queries well in advance of attendance. While this same nurse will accompany the child and family to the PET/MR unit to ensure adherence to general MR safety, they are supervised at all times by a MR authorised person while in the scanning room.

Equipment safety: A MR safe Medrad Continuum pump (Medrad, Warrendale, USA) is used to provide a continuous glucose infusion during the scan, which is operated by either radiographers or GOSH nurses trained in how to use it safely. For those family members/staff entering the scan room a final check for ferrous material is performed in the ante-room just before the scanning room and Metrasens Ferroguard detectors (Metrasens, Malvern, UK) are in place immediately outside the scan room as an additional safety measure to check for any forgotten about ferrous items. GA equipment is not required (see below)

Patient Set-up: Speed is of the essence at this stage since the patients have now been administered ~ 150-200MBq of 18F-DOPA. The parents are encouraged to keep a distance from the child unless there is undue stress and anxiety exhibited. However, the patients are orally sedated by a GOSH clinical nurse specialist, prior to radiopharmaceutical administration, in order to minimise movement during the scan. Movement can be furthered minimised by tightly swaddling small children (under a year) in a blanket and using a firmly secured torso coil The patient’s vital signs are monitored using a GE MRI monitor (GE Healthcare, Milwaukee, USA). Nurses personally monitor patients either from inside the scan room or from the console operator area using a slave monitor located in the control room (Cahoon, 2011).

Optimising Image protocol: Minimising scan time and acoustic noise reduction: Although imaging at 3T increases SNR improving spatial and temporal resolution consideration must be made of SAR limits for advanced sequences when used in paediatric imaging. In addition increased field strength results in much higher acoustic noise levels. Although every care is taken to minimise movement we have found that image quality is also drastically improved
by using respiratory navigated sequences, which minimise breathing artefacts. Patients are
given oral sedation instead of a general anaesthetic, which reduces cost and risk of the
procedure. (Dagia and Ditchfield, 2008). Ear plugs and headphones are used to protect the
hearing of paediatric patients as well as utilising specific Siemens noise reduction
sequences; Whisper gradients, which drastically reduce the acoustic noise associated with
gradient coil modulation.

Despite additional time taken to screen patients, family members and accompanying medical
staff the time and costs saved when compared to having to cancel a scan at the last minute
due to contra-indications is significant – although essential for a nuclear medicine
department in terms of screening prior to injection of radioactive material we would
recommend this practice to be taken by general radiology departments that have to re-
appointment 4-5 patients per week. And finally, while we don’t rely on the Metrasens
Detectors as the only means of screening patients and family members we do find them to
be of added benefit not least in assurance.
The modern face of equipment management in the NHS
Tuesday 19th November

Patient experience and how important it is for a modern healthcare context
Damian Chick  Email: damian@momentumbusinessclub.co.uk

Key themes: the service users should always be at the centre of service delivery and service redesign because to deliver modern health care services everyone who is involved need to take responsibility and a certain level of ownership otherwise with smaller budgets. We will not be able to deliver a world-class health service and keep pushing back the boundaries so that the population in the UK can have the health care service which they deserve. We can only achieve this if everyone starts taking an active role in their services therefore, in bracing active patient relationships and allowing the power dynamics between patients and practitioners to come together in true partnership working
A Step-change has taken place in the way the NHS is being governed and the monitoring which is taking place. The past year has seen publication of 3 major reports into governance and safety across the NHS – The Francis report into how extensive regulation failed to detect high mortality at Mid Staffs, The Keogh Review into 14 further hospitals with high mortality rates, and the Berwick report into staffing levels and the need for criminal investigations into falsification of data.

In July, Professor Sir Mike Richards, the new Chief Inspector of Hospitals announced a new inspection regime to be carried out by the CQC in England. No longer is it down to inspectors to search for problems with a microscope. The new approach requires all NHS professionals to raise concerns, and failing to do so is not only professional misconduct, but could be a criminal offence.

How does this affect the Clinical Engineering profession? How strong is the governance of medical devices in our Trust? How far do our responsibilities extend in providing leadership in the governance of medical devices? Should we raise concerns if we think there are gaps and crevices in medical device governance?

This paper will identify issues that we may all face about the governance arrangements for medical devices, will ask questions about how far our responsibilities as Clinical Engineers reach, and about how to tackle some of these challenges.
Evidence based maintenance – safe, legal and quality compliant?

Philip Coulthard, Medical Physics Cooperative Ltd, Hexham, Northumberland, Email: phil@northernphysics.co.uk

Medical Physics Cooperative (MPCL), is an independent ISO 9001 provider of Radiation Protection Advice and Radiology Equipment Services, listed on the NHS Supply Chain equipment maintenance framework agreement. We are an example of a chaordic1, self organizing structure trading as a Secondary Cooperative.

MPCL offers a unique maintenance contract that establishes a contingency fund to cover equipment failure. This innovative offer has potential for savings in the order of 40% to 60% compared with conventional comprehensive maintenance contracts, without compromising quality.

Radiology departments have been reluctant to hold explicit contingency funds in house for fear that the Trust would appropriate unspent monies for use elsewhere. Our proposed mechanism ring fences the fund. We have identified the potential and have the service capability to provide savings coupled with uptime continuity that cannot be realised by other public accounting methods.

The questions raised by the success of such a structure, in identify this new service model and in having the intrinsic resilience and creativity in overcoming the many obstacles to get on the framework, with such an offer are:

1. What makes such a structure resilient and creative?

2. Should large institutions welcome such structures and look to adapt to improve their own resilience?

3. Is there a way that by working together, we can bring about change, which has mutual benefit, without compromising safety, is legal and maintains quality?

We hope to address these questions in the presentation.

1 Chaordic Structures, “One From Many” by Dee Hock
Cost comparison of equipment library and rental for pressure relief equipment
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Email: megan.dale@wales.nhs.uk
Megan Dale, Susan Peirce, Grace Carolan-Rees

Introduction
Two hospitals with similar numbers of beds and annual admissions, but very different methods of pressure relief equipment provision (specifically dynamic mattresses) were compared. Hospital A mainly uses a rental system, with wards ordering individually, under an overall contract. Hospital B purchases dynamic mattresses and uses an equipment library to loan them to the wards. We compared the costs of each system and described the service offered by each.

Method
A simple cost model was developed in Excel. To obtain model inputs, colleagues from each location were asked to provide information from their records for the period of January 2012 to December 2012. This included items such as rental rates and days used, capital cost of equipment, cost of staff to maintain, clean and deliver mattresses and other maintenance costs. It was not possible to estimate the cost of the space used for the equipment library, however the amount of space used was measured.

Comparing the level of service provided and its effectiveness is more complex and we have only partially addressed this. We were able to calculate (with some extrapolation) the number of days use of mattresses over the year, and described the process for requesting and obtaining mattresses. Incidence of pressure ulcers was provided on request by the hospitals, however there are numerous confounding factors that affect this figure.

Results

Calculation of cost per mattress day and mattress days per 1000 Finished Consultant Episode (FCE) bed days

<table>
<thead>
<tr>
<th></th>
<th>Annual Cost</th>
<th>Mattress Days</th>
<th>Cost per mattress day</th>
<th>FCE Bed Days</th>
<th>Mattresses per 1000 FCE Bed Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (mainly rental)</td>
<td>£688,437</td>
<td>143,156</td>
<td>£4.81</td>
<td>295,334</td>
<td>485</td>
</tr>
<tr>
<td>B (mainly library)</td>
<td>£338,382</td>
<td>109,100</td>
<td>£3.10</td>
<td>297,686</td>
<td>366</td>
</tr>
</tbody>
</table>

More hospital acquired grade 3 & 4 pressure ulcers were recorded in hospital A (rental) than B (library), over the time studied, however there are likely to be numerous contributing factors to this.

Discussion
An equipment library system can be operated at a lower cost than a rental system, but this does not identify the key factors in its success. Not every equipment library will run at the same cost, and another hospital could potentially operate a rental system at lower cost. It is also important to note that these costs apply to systems that are established.

Conclusion
The resources used by Hospital A (rental agreement) are greater than those used by Hospital B (equipment library), for similar size hospitals and without reducing the incidence of pressure ulcers.

The Facts from Cambridge University Hospitals Cambridge using RFID
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This short presentation will help illustrate and explain some of the Myths which are associated with RFID deployment in healthcare. RFID can be an inexpensive solution and whether Active, Passive, Wireless or handheld systems are used there are positive benefits to the management of medical devices to drive improvements across all areas from PPM, patient safety, Training, Risk Management, compliance and cost savings.
Unlocking the potential to deliver healthcare and productivity benefits for the NHS through better medical equipment asset management

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The NHS has an installed medical equipment asset base of about £5 billion at replacement value and an annual cost of provision and management in excess of £1bn. This covers big ticket medical equipment like MRI and CT scanners down to basic monitors costing a few thousand pounds. This equipment is vital for the delivery of modern healthcare and is also the key to unlocking productivity benefits on an NHS cost base in excess of £120bn pa. A relatively minor investment in new technology could have a direct and positive effect on total costs.

What is Asset Management?
Asset management can be defined as the management and coordination of asset selection, operation, maintenance and renewal. The primary purpose is to use assets to deliver value and achieve organisational objectives. For the NHS this means better, more effective and efficient healthcare which is sustainable.

Key characteristics of best practice asset management for the NHS comprise:
- An Asset Management Strategy for the NHS giving clear direction and linked to key clinical objectives like the National Cancer Strategy
- Asset Management Governance: Policies, standards, Leadership, culture, information, decision making rationales – which provide the operational framework for effective management
- Operational planning and management execution: Local delivery of asset management plans, operational metrics, procurement benefits, whole life costs and medical outcomes.

What are the benefits of best practice Asset Management?
Asset management aims to optimise the benefits of the medical equipment installed base for the NHS. Examples include:
- Reduced capital and operational costs: buying the right technology, at the right price, in the right quantity at the right time and to the optimum maintenance level.
- Improve operational performance: reduce failure rates and increase availability & utilisation of equipment for medical benefits
- Optimise and reduce whole life ownership costs
- Lower supplier and supply chain costs
- Reduce legal risks and insurance premiums associated with buying and operating assets: compliance with procurement regulations, CQC standards
- Rapid adoption of the most appropriate new technologies to enable better healthcare
- Strategic direction and control and risk management
- Whole NHS system cost reduction and productivity improvement

How Do NHS Supply Chain envisage taking advantage of best practice?
NHS Supply Chain believes that asset management is a discipline that helps organisations achieve their defined purpose. Its application within the NHS presents a major opportunity to drive performance by learning from best practice in industry.

NHS Supply Chain is developing an NHS blue print to provide guidance and decision support methods in order to enable the NHS to take advantage of best practice and shared learnings throughout the NHS. In addition, a bespoke assessment tool is being created to help determine where an individual trust is positioned from an asset management maturity perspective in order to guide the implementation path and take most effective use of the blue print.
By working strategically with us on long term initiatives, customers can be sure that they are making the most efficient use of their time and internal processes. Understanding the real needs of your trust and other healthcare organisations in the NHS is at the heart of our operation. Trusts and NHS Supply Chain can come together to share best practice and develop solutions for the broader NHS quality of patient care and safety.
Avensys UK Ltd Practical Based Training

Since Avensys was established back in 2006, we have maintained our commitment to continual investment in the delivery of biomedical equipment, technical training courses for medical engineering departments and end users. We can offer level 3 qualifications in Biomedical Engineering and a Higher National Diploma in Medical Equipment Technologies, all practical work is carried out in our established and dedicated training facility based in Kidderminster West Midlands.

Our expertise and experience (Now spanning 6 decades) in this area has proved incredibly valuable to both technical and non-technical staff of the NHS, Private Sector, MoD and Training Establishments throughout the UK

Avensys had direct involvement in writing the UK’s National Occupational Standards (NOS) for Medical Equipment Servicing for SEMTA (The Sector Skills Council for Science, Engineering and Manufacturing Technologies in the UK). It is these standards that all of our level 3 certified training modules have been directly mapped to. A direct link to the NOS can be found via this website.

http://www.avensysmedical.co.uk/
Improving Tracking and Value for Money of External Equipment Maintenance Contracts

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We frequently find that equipment suppliers send in their maintenance renewal quotes late. We often find that it is incorrect with wrong inventory and service options. A consequence of it being late is that there is pressure to renew quickly to maintain cover. This is usually at a higher price with no options to negotiate.

To break the cycle we embarked on a 3-year project to take control of the situation in our Trust. This is an area where maintenance costs are multi-million pounds and there is good scope for non-pay reductions to help the Trust meet its CRES targets. We formed a specialist team involving MEMO Clinical Engineers, Finance accountants, Procurement specialists and Heads of departments.

This paper describes the process to reduce spend on maintenance whilst keeping the quality, patient safety and departmental availability satisfactory. Our Trust is a large multi-hospital Teaching Trust. We gathered data on all known contracts through the purchasing records; we created a specific database of these contracts and costs and made it available to finance directors and departmental heads in an easily searchable format. We then analysed the contracts to see where there were duplicates, overlapping and multi-departmental contracts. By pulling these together we were able to negotiate better discounts for the Trust.

We found a number of incidents where contracts were paid for but the company did not do the maintenance, or put in another bill for the call-out—even though it should have been covered by the contract! We found that departments were not building in Key Performance Indicators (KPI’s) into their contracts and were not monitoring them effectively.

This is an on-going exercise and we benchmark frequently with other Trusts including our neighbouring Trusts. We will also say where a move to a cheaper 3rd party supplier was unsatisfactory on some types of equipment. We will discuss further examples of good practice and areas for future savings.
Clinical Engineering Leading Healthcare Technology Management

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Introduction
Clinical Engineering has been defined as ‘the application to healthcare technology of engineering skills and management in order to support and advance patient care.’ Their formal education and training both in engineering and clinical knowledge enables Clinical Engineers to understand both the clinical application and the technology involved.

Healthcare Technology Management (HTM) has been defined as managing the selection, maintenance, integration and safe and effective use of medical equipment and systems (1). Equipment can range from a simple medical gas flowmeter to a complex MRI scanner system. All significantly impact on the safety and quality of care provided to patients. All need to be managed on a whole life basis.

Managing healthcare technology equipment
The authors have identified features of HTM, some unique to this field, which require a specific approach and which make Clinical Engineers uniquely qualified to lead the interdisciplinary thinking that must guide the risk management processes underpinning HTM strategy.

The effective use of resources to manage healthcare technology equipment (which is always seen as diverting money from direct patient care) requires engineering and clinical judgement. Although all users of medical equipment have a role in HTM, only Clinical Engineers have this as one of their core functions. They therefore have a responsibility to lead, innovate and develop efficient and effective HTM systems.

The presentation will describe the GS1 organisation and the work it is doing in promoting the creation and adoption of standards in global healthcare. An overview will be provided of GS1 standards for the identification, capture and sharing of information concerning medical products and devices from their manufacture through procurement, maintenance and on to the point of use. The presentation will summarise how GS1 standards are being used within the NHS for patient wrist bands, surgical instrument tracking, procurement and inventory management.

GS1 UK is currently working with the Health and Social Care Information Centre to develop guidelines for the use of GS1 standards for managing a variety of health related assets including medical equipment, loan stock, gas cylinders and pathology. The presentation will outline current thinking on how GS1 standards can be used in the management of medical equipment.
This presentation will give a brief glimpse into the role of an Independent Service Organisation (ISO) in equipment management in the NHS, exploring the services that are offered and how they might meet the requirements of all or part of the equipment management lifecycle.

Find out more about Asteral services on the website: http://www.asteral.com/