A Transmission Ionisation Beam-Imager for Radiotherapy Verification

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Introduction Electronic portal imagers are not entirely satisfactory for verification of multi-leaf collimator position and dosimetry of intensity-modulated radiotherapy, and their images are difficult to interpret when the intensity modulations are superimposed on the patient anatomy. This project is an initial study of a method for measuring the input dose pattern by means of a pixellated air-ionisation chamber placed in the linac accessory tray. The pixel size is 1 cm, which allows the entire image to be read out between pulses, and used to calibrate a portal image; to verify the position of the multi-leaf collimator with respect to delivered dose; and to check beam flatness and symmetry. This study presents the results of optimising the chamber and read-out electronics design.

Method A test chamber was constructed of one-dimensional strip electrodes, with various build-up, plate separation and electrode design. The resolution of the chamber was characterised by its response to a 1-cm wide field, and the magnitude and noise characteristics of the signal with large fields.

Five different designs for systems to measure the collected charge have been studied with respect to sensitivity, linearity, noise, power consumption, cost and scalability to 1600 pixels.

Results Application of low atomic-number build-up and reduction of plate separation were the most effective methods to improve resolution. A sharp response was obtained, with tail below 10% of the peak signal observed for several centimetres. Preliminary electronic tests show that the signals can be measured with adequate precision.

Conclusion The study shows that the system should repay further development.

Characterising the distortion of an MR sequence for use in radiotherapy treatment planning

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Introduction Magnetic resonance (MR) images are used in combination with computed tomography (CT) images to aid volume definition and reduce uncertainties in the localisation of volumes in sites such as the central nervous system. Precise registration of the MR and CT images is required for treatment planning. Geometrical and intensity distortions arise in MR images as a result of gradient non-linearities and inhomogeneities in the main magnetic field. Once characterised, the extent of these distortions must be assessed and either accepted or corrected prior to registration with CT data. A study has been initiated to assess the contribution of MRI to radiotherapy (CT) treatment planning of skull base tumours. The aim of this study was to assess the distortion of the MR sequence used for this work.

Method A clinical protocol was established for the MR phase of the study. All scans were performed on a Siemens 1.5T Magnetom. Images of a linear test

object were used to map the MR gradient-based distortions in three dimensions over the volume of interest. Experiments were performed to justify the use of these maps on patient images. The ability of the Chang and Fitzpatrick correction technique [1] to remove susceptibility-based distortions and chemical shift effects has been assessed.

Results Within experimental error, the spatial information in images acquired with the head and neck coil is identical to images acquired with the body coil. The introduction of phase oversampling has no effect on the overall gradient effects. The MR gradient-based distortion of the system to date is within 2mm over the volume of interest.

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The Dosimetric Properties of a Mini-MLC – Implications on Patient Treatment

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Introduction Multileaf collimators (MLCs) are used in conformal radiotherapy to form irregularly shaped fields, the resolution depending on the leaf thickness. Conventional MLCs have a projected leaf thickness of 1 cm at the isocentre while a mini-MLC (mMLC) recently purchased at Clatterbridge Centre of Oncology (CCO) has a projected leaf thickness of 2.5 mm.

Methods In this project dosimetric data has been obtained to characterise the mMLC has on the dose distributions. Radiation fields collimated using the mMLC were then modelled using the Plato treatment planning system. Dose distributions were calculated for patients treated with prostate cancer collimated using MLCs of leaf thickness 1 cm and 2.5 mm. Differences in dose distributions were assessed and the dose escalation made possible by the improved resolution of the mMLC was calculated, using biological NTCP modelling. All of the models used have been fitted to real clinical data obtained from either the literature or a randomised trial of conformal radiotherapy treatment of prostate cancer.

Results The mMLC gave a penumbra reduction averaged over angles of 1 mm. This leads to equivalent target coverage with better normal tissue sparing, giving a net increase in dose of 0.35 Gy corresponding to a gain in tumour control of 0.29%.

Conclusion Errors due to set up and organ movement have not been taken into account when calculating the dose escalation. The limited gain in tumour control will diminish further if these errors are taken into account.

Modelling the CR imaging process to create threshold contrast detail detectability images using analytical methods

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Introduction Each stage in imaging a threshold contrast detail detectability (TCDD) test object with computed radiography (CR) is modelled to create a simulated image. This can then be compared to images created using a real TCDD test object and CR

system. By using the same parameters in the real and simulated images, the quality of the model can be measured. The model can then be used to demonstrate how different variables affect the image quality in a CR system. The simulated images can also be used to assess scorer sensitivity and to test receiver operating characteristics (ROC analysis). They can also be used to introduce the ideas of TCDD test objects and how to measure them to people before being required to score them in the field.

Methods Each stage of the imaging chain will be studied to explore and model the number of photons or electrons, noise and unsharpness sources that are introduced and any gain or loss involved. The source of this information will be primarily from published literature. X-ray spectra will be taken from published data, and incorporated into the model to enable different energies and filtration to be used. The modelling will be done using IDL (interactive data language). By making changes to the test object imaged in the simulation, it is hoped that noise power spectrum (NPS), modulation transfer function (MTF) and detective quantum efficiency (DQE) measurements can be made. This will enable further measurement of the quality of the model.

This work is currently in progress. It forms part of an MSc project that will be submitted at the beginning of August 2002.

Comparison of Film Screen and Computed Radiography (CR) Image Quality for Chest Imaging

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Introduction The aim if this project was to compare the image quality of film screen and CR for chest examinations.

Methods A series of images of the CDRAD threshold contrast detail phantom were acquired at 75kVp 90kVp and 125kVp for a range of exposures with both CR and film screen. The phantom was placed within 9cm of perspex to simulate the scatter from an adult chest. Entrance surface dose and receptor dose were measured. CR images were printed onto film and viewed at a fixed distance from a masked light-box. The threshold contrast index values were used to calculate an image quality index for each image. Comparisons of the image quality against the variables of dose, beam energy and imaging system were made.

Results CR shows a wider dynamic range than film. Film image quality dropped off at optical densities above 2.5 whilst CR improved with exposure until structural noise became comparable to quantum noise. Under AEC conditions CR produced quality indices 13% 9% and 11% lower than film screen at 125kVp 90kVp and 75kVp respectively. At these energies film outperformed CR over a range of exposures spanning a factor of 5 ,4, and 3 respectively.

Conclusion Film screen has higher quality indices than CR for AEC exposures under the optimum conditions of this test. Exit exposures from chest

images vary by a factor of approximately 5 (lung to mediastinum). At the energies investigated CR produced comparable image quality to film at these extremes of exposure. Comparison of image quality between these systems is non-trivial due to inherent differences in their dose responses, and the nature of the diagnostic information required from chest images.

A novel algorithm for the measurement of kidney area from images acquired for ^{99m}Tc-DTPA renograms

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Introduction Renal artery stenosis (RAS) is a common cause of secondary hypertension. ^{99m}Tc-DTPA studies are routinely performed for the investigation of RAS. It is hypothesised that the projected kidney areas in the images will yield additional prognostic information. A novel automatic image analysis technique was developed to measure area; it was compared with theory using software phantoms and with a pre-existing semiautomatic nuclear medicine technique.

Method Single composite frames (2-3 minutes post-injection) were obtained from 30 normal studies (mean area by semiautomatic method: 40.2±5.3cm^2). 40 phantoms (mean area 38.4±18.1cm^2) with ranges of contrast and noise found in normal studies were constructed by modelling the kidneys as ellipsoids of uniform activity set within a torso of background activity.

The novel technique was calibrated against the phantoms and compared with the semiautomatic technique for left kidneys in the normal images using Bland-Altman analysis.

Results For the normal images, the mean bias (novel-semiautomatic) was 12.9cm^2 (95% CI 11.6-14.2cm^2). For the phantoms of known area the mean bias ($\pi r_1 r_2$-semiautomatic) was 9.7cm^2 (95% CI 8.6-10.9cm^2).

The differences were found to have a strong dependence on kidney area. Further, the measurement differences were found to depend linearly on the perimeter of the projected ellipsoids. The bias corresponds to a linear boundary placement difference of approximately 1 pixel.

Conclusion Analysis of phantom images suggests that the novel technique is more accurate than the semiautomatic technique, at least in normally functioning kidneys. The dependence on perimeter suggests that the disagreement in edge placement dominates contributions to the bias. Further work to verify the novel technique against physical phantoms or a different imaging modality is required.

Is it possible to use a modern gamma camera to make in-vivo vitamin B_{12} absorption measurements?

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Introduction To overcome the errors arising from an incomplete urine sample in in-vitro Schilling tests, some centres use a whole-body counter to make an in-vivo assessment of vitamin B_{12} absorption. However, most centres do not have such a counting system. The aim of this study is to investigate

whether a modern triple-headed thick (19mm) crystal gamma camera can be used to make an in-vivo assessment of B_{12} absorption.

Method Since the gamma camera was used purely as a counting device, all measurements were made with collimators removed and to ensure good counting geometry, detectors were placed in a triangular configuration. To assess background activity levels a series of five minute acquisitions were made in low activity environments. A series of five minute acquisitions were made using aliquots of ^{57}Co ranging in activity between 200 Bq and 20 kBq. Summing the total counts from all three heads, a plot of counts against activity was made. Using 3 s.d. confidence levels, the plot was extrapolated to derive the smallest measurable activity with our system/environment.

Results The lowest measurable activity with our system and environment was 39 Bq. Although these measurements were made with low levels of attenuation, they are well below the 1-8% absorption levels found in pernicious anaemia given that the administered activity is 20 kBq.

Conclusions A modern triple headed thick crystal gamma camera can be used to make in-vivo measurements of vitamin B_{12} absorption. A study to assess the equivalence of in-vitro and gamma camera in-vivo measurements will follow.

What does Laser Doppler and cold challenge tell us about Raynaud's phenomenon

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Laser Doppler flowmetry (LDF) is a technique used to evaluate peripheral blood flow in Raynaud's phenomenon by monitoring the concentration and speed of red blood cells. Raynaud's patients describe symptoms of acral discolouration and paraesthesia upon exposure to cold conditions.

This study establishes the normal LDF response to cold challenge of the hands, and compares it to that of Raynaud's phenomenon patients. To date, 52 Raynaud's phenomenon patients and 35 control subjects have been analysed.

After a period of acclimatisation, laser Doppler probes were attached to the pulp of the middle finger of each hand, and each subject was monitored for five minutes to establish a baseline measurement. The subject then immersed both hands in a waterbath at a temperature of $15\pm1°C$ for one minute, keeping the laser-Doppler probes in place. The speed, concentration and flux of the blood cells were then measured for ten minutes post provocation stimulus.

Analysis has been undertaken on LDF measurements recorded at baseline, one minute and 5 minutes post cold challenge. There was found to be no significant difference in erythrocyte speed and flux between Raynaud's and normal subjects at baseline, one minute and five minutes. Significant differences in concentration ($P<0.01$) were, however observed at all these time points. Significant differences were observed in the time it took to recover to baseline flux value following cold challenge in Raynaud's subjects and normal subjects.

The evaluation of laser-Doppler concentration may be an effective measurement for discriminating Raynaud's subjects from normals.

Doppler ultrasound Resistance Index and Pulsatility Index blood flow measurements in axillary lymph nodes

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Introduction Spread of cancer to lymph nodes is an important consideration in the staging of breast cancer. Lymph nodes can be imaged using ultrasound. Intranodal blood flow parameters can also be ascertained by the use of Power Doppler imaging and Pulsed Wave Doppler. A metastatic deposit in a node may compress the intranodal artery of a node causing an increase in vascular resistance. The use of Spectral Doppler Indices to differentiate between metastatic and normal nodes has been reported on in literature by several authors [1]-[6]. It has been found that metastatic nodes give higher Doppler Indices than normal nodes. Hence, it is postulated that Doppler Indices relate to the physical properties of the nodal vasculature.

Purpose Does compression of the intranodal arteries give rise to variation in the Resistance Index and Pulsatility Index in normal lymph nodes?

Methods Normal lymph nodes will be investigated. Individual nodes in the underarm region will be compressed while being investigated with Power Doppler Ultrasound. Pulsatile waveforms of arterial intranodal blood flow will be recorded. Doppler Spectral Indices will be calculated using a Signal Processing package. The pressure applied to a node will be varied by pressing on the skin with the ultrasound transducer. The pressure will be quantified by a small bladder attached to a U-tube water manometer The bladder will be positioned between the transducer and the skin.

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Evaluating electronic assistive technology – the wiseDX system as a case study

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Introduction Electronic assistive technology (EAT) is provided with the aim of maximising the independence of people with impairments, either physical and/or sensory, which limit their ability to carry out activities and participate in society. An item of equipment can only meet this goal if it can provide the functions required by likely users in an efficient and safe manner. In choosing equipment to provide to users, a service can either refer to the results of a centrally managed evaluation process or carry out local evaluations of the devices. This presentation describes the salient features of a local evaluation of the wiseDX integrated EAT system and the resulting findings as an example of the process.

Methods The evaluation process included three main elements and the first of these was a technical investigation into the system's functional capabilities. The second aspect was a series of benchmark tests which took the form of typical tasks that a user may wish to perform and these allowed the efficiency and ease of use of the system to be assessed. The third element in the process was an informal safety assessment which investigated the measures in place to reduce to acceptable levels the likelihood of occurrence of those potential hazards with the most severe consequences.

Results The evaluation of the wiseDX system identified some issues that required rectification before the equipment could be considered for provision to users. This information was conveyed to the system designer which allowed this to occur prior to the device being mass-produced.

Conclusion The evaluation of the wiseDX system demonstrates the purpose of the process in ensuring the equipment is suitable for supply to NHS clients and in addition the provision of valuable feedback to the manufacturers will allow the optimisation of their products.

Chapter 5. Grade A Session