Extremity Doses to Interventional Radiologists

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Introduction Radiologists performing interventional procedures often have to stand close to the x-ray beam to carry out manipulations. Doses to their hands may be high, as they are close to the x-ray field, and to the legs when not protected by lead screens. Studies have been undertaken at seven hospitals using TLDs to determine distributions of dose across the hands and legs of radiologists performing interventional procedures and to determine an effective way for monitoring the most exposed parts.

Methods Over one hundred procedures were measured, using eighteen TLDs, seven on each hand and two on each leg.

Results Results show that for most procedures the dose to the finger tips is greatest, decreasing along the length of the hand. However, for embolisation procedures the gradient was reversed with the wrist receiving the highest dose. The highest hand doses were for biliary and Transjugular intrahepatic porto-systemic shunts (TIPS), with mean hand doses of 0.05-1.5 mSv and leg doses of 0.5-2.6 mSv per procedure. For stenting, embolisation and angioplasty, the ranges of mean doses per procedure to the hands and legs were 0.05-0.2 mSv and 0.02-0.6 mSv respectively. A ratio of 1.1-1.4 existed between the dose to the most exposed part and the dose recorded by a ring dosimeter. No relationship was found between dose-area product (DAP) and hand dose, but a linear relationship was observed with leg dose.

Conclusion A useful rule of thumb is that a DAP of 100 Gy cm^2 gives a dose of 1 mSv to the legs, if no shielding is present. This study has provided data on radiation doses to the hands and legs from different procedures. Guidance on methodology for dose monitoring and relationships which can be employed in risk assessments have been determined.

Establishment of Reference Dose Levels in Paediatric Diagnostic Imaging Examinations in Ireland

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Introduction Children are at a greater risk from exposure to ionising radiation than adults[1]. The EU directive 97/43/Euraton[2] has placed a legal obligation on all member states to establish diagnostic reference levels (DRLs). Establishment of local and national reference levels will play a major role in the effective implementation of the Medical Exposure Directive. The aim of this project was to survey paediatric doses, in Ireland, for a range of radiographic examinations to establish DRLs. An assessment of the amount and specific types of X-Ray examinations performed in three of the largest paediatric hospitals in Ireland was performed.

Method Entrance surface dose (ESD) is the criterion normally used to set reference dose levels[3]. ESD can be measured in two ways: using TLDs or with a DAP meter. This study used a new type of TLD chip (TLD-100H) that has been developed in recent years. Initial tests done using the standard TLD-100 showed that this chip was not sensitive enough to measure the low doses used in paediatric diagnostic

examinations. TLD-100H is made from LiF:Mg,Cu,P and is estimated to be 15 times more sensitive than the standard TLD-100[4]. TLD-100H has a very low detection threshold, of a fraction of μGy.

Results A survey of current practices showed that the three most common paediatric X-ray examinations performed in Ireland were chest, pelvis and abdomen. ESD measurements were made for these examinations in three of the largest paediatric hospitals in Ireland. Measured doses and radiographic technique were compared to the guidelines set by the CEC on Quality Criteria[5]. The results showed that many of the guidelines set by the CEC were not being followed especially those on added filtration. Dose measurements made in this survey have been used to set up local DRLs and can be used as a template for national DRLs.

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The Influence of Linear Tomography on Effective Dose

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Introduction Conventional (or linear) Tomography (TOMO) is an optional component of intravenous urography (IVU) resulting in increased radiation dose to the patient but providing improved visualisation at a predetermined depth within the subject. Due to the obliquity of the incident beam during TOMO, the relationship between Effective Dose (ED), Dose area product (DAP) and x-ray technique factors may be more complex than in other applications. We wished to investigate the relationship between these various indicators of dose and to establish local examination frequencies and DAP levels.

Method An anthropomorphic phantom with dimensions and radiographic properties comparable to that of a human adult female of standard size was loaded with thermo-luminescent (TLD) dosimeters and exposed on two separate occasions in accordance with local protocols for IVU examination with and without TOMO. ED was calculated from individual organ dose and compared with estimates based on DAP and x-ray technique factors using standard conversions. Uncertainty in estimation of ED using TLD has been estimated at +/-25%.

Results ED with and without TOMO was 0.66mSv and 0.40mSv respectively, based on TLD; 0.47 and 0.32mSv based on DAP and 0.41 and 0.27mSv based on x-ray technique factors. Examination details of 438 IVU procedures at two centres were recorded

over a twelve-month period indicating median DAP values of 9.3Gycm^2 with TOMO and 4.9Gycm^2 without.

Conclusions ED for all techniques was similar bearing in mind the uncertainties involved and may be estimated from either DAP or from x-ray technique factors.

The Effects of Sub-optimal Viewing Conditions on the Detection of Low Contrast Objects

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Introduction Until recently, the establishment and maintenance of satisfactory viewing conditions have been given a relatively low priority compared with the effort expended in optimising the process used to produce the radiographic image. However, poor viewing conditions can have a significant deleterious effect on the performance of the observer and current trends in mammography such as the use of high optical density films makes a study of this area overdue.

Methods and Results Investigations were performed to determine the effects of sub-optimal viewing conditions on the performance of an observer. In each case, the viewing conditions were characterised by various photometric quantities and the ability of the observer to detect low contrast objects assessed using contrast-detail methods. The decrease in observer performance was quantified as the increase in threshold contrast and relationships were derived allowing the observed reduction in performance to be described in terms of basic photometric quantities. On the basis of these findings, a protocol has been developed for assessing viewing conditions in mammography.

Conclusions This investigation demonstrates the significant effect that viewing conditions can have on the performance of the observer. It has been shown that the effect on the observer can be related to basic photometric measurements and that these measurements can form the basis of a protocol for assessing viewing conditions.

Systematic Selection of Technique Factors in Paediatric CT

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Introduction Paediatric CT examinations are performed relatively rarely in most centres and the range of patient sizes encountered is large. It is therefore difficult to make a selection of technique factors which produce a consistently optimised balance between radiation dose and image quality. In this work a method is suggested such that the images produced for paediatric patients will be similar in terms of signal-to-noise ratio to the images produced for the equivalent adult examination, the technique factors for which will be much better established in most centres.

Methods A simple exponential attenuation model is proposed incorporating effective linear attenuation coefficients for head, chest and abdominal examinations. These attenuations coefficients were initially established from a series of measurements on adult and paediatric anthropomorphic phantoms, then extended for a range of tube potentials and beam qualities using a beam spectral model.

Results The approach to technique factor selection was applied to head, chest and abdominal examinations of neonatal and 1,5,10 and 15 year-old phantoms and the resulting noise levels compared to that of the baseline adult examinations. Within the considerable experimental errors, the noise was seen to be effectively constant as intended.

Conclusion A simple method to select paediatric CT technique factors has been investigated which could be used to produce consistent image quality over large patient size variations.

The Optimisation of Standard Protocols on a Multislice CT Scanner - a Work In Progress

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Introduction The widespread introduction of multislice CT scanners brings with it the risk that dose to the population from CT scanning will continue to rise [1]. This work compares a four slice CT scanner (Scanner B) to an existing single slice helical scanner (Scanner A) and recommends optimised protocols based on image noise and dose [2].

Methods On both scanners, image noise and $CTDI_W$ were measured for the standard protocol for each of the ten most frequent examination types. These measurements revealed that, in general, the manufacturer's programmed protocols on Scanner B used thinner slices, had lower noise and gave more dose than Scanner A.

The protocols on Scanner A have been optimised on an ad hoc basis since its installation in 1997, so it was decided to use these as a local standard.

For each of the protocols on Scanner B, the mAs required to give the same $CTDI_W$ as Scanner A was calculated. Simple Poisson statistics were used to predict the resulting noise. Where appropriate, the effect of changing the slice width was predicted. The accuracy of these predictions was checked by measurement.

The effects of pitch and reconstruction algorithm on noise were investigated.

Results and Conclusions Preliminary measurements indicate that it is possible to reduce the doses on the multislice scanner to equal those on the single slice scanner, with little cost in image noise for thinner slice widths. It is intended to present the results of clinical implementation of these recommendations. However, multislice scanners may allow improvements in technique (e.g. 3D reconstruction) that justify higher doses. For these cases, the clinical justifications will be presented.

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Determination of an image quality index from threshold contrast detail diagrams.

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Introduction Assessment of image quality is of fundamental importance in the evaluation of image intensifier fluoroscopy systems. Many image quality descriptors have been developed, but none give a consistent all-encompassing inter-comparison

between imaging units. The aim of this work was to develop a novel image quality (IQ) index using threshold contrast detail diagram data rather than combining noise and resolution measurements.

Method A threshold contrast detail test object has been used to obtain data on nineteen fluoroscopy units. The data recorded has been plotted as threshold contrast versus object size and fitted to a rectangular hyperbola of the form $xy = c^2$. The distance, $\sqrt{2}c$, from the origin to the curve apex has been calculated and used to develop a measure of IQ. Threshold Contrast Detail Diagrams (TCDDs) and Threshold Detection Index Diagrams (TDIDs) have been compared with c^{-2}, a proposed IQ index. Comparisons have also been made with other image quality descriptors.

Results When the correlation of contrast versus reciprocal object size is >95%, the TCDD can be accurately plotted as a rectangular hyperbola. Data from 80% of the fluoroscopy units assessed can be represented in this way.
Conclusion: The quantity c^{-2} is potentially a useful IQ indicator for threshold contrast detail data that can be fitted to a rectangular hyperbola.

Evaluation of Trabecular Bone Direction from X-ray

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Introduction Trabecular structure quantification has become important in assessing bone quality[1]. Such assessment is preferable from radiographs, which are widely available and unique towards imaging metallic implants. This study evaluated the efficiency of four techniques towards detecting trabecular direction. Additionally, a test was investigated to ascertain the presence of a linear trabecular structure.

Materials and Methods Clinical femoral radiographs were analysed and used as models to create synthetic images. These latter images enabled the definition of a known linear trabecular direction. To simulate radiographs, Laplacian noise was added to the synthetic images at 7 levels. Four methods were employed to infer the trabecular orientation: (a) Co-occurrence matrix[2], (b) Range-length matrix[2], (c) Minkowsky fractal[3] and (d) Spatial-frequency[1]. Precision and accuracy were calculated by comparing the measured to the known trabecular direction. Each measurement was repeated 30 times to obtain statistical significance.

Results In non-noisy synthetic images, all methods correctly inferred the trabecular direction. However, in noisy synthetic images, only methods (a) and (d) performed well, up to a 500-noise-level (accuracy>99%, SD<3^0). At this level, the processed signal of method (a) still presented a peak providing the orientation of amplitude 1.7 times greater than the rest of the signal. Similar results were obtained for clinical images. Furthermore, method (a) requires prior trabecular dimension knowledge while (d) is prerequisite-free.

Conclusion Spatial-frequency analysis is capable of inferring trabecular direction from radiographs, even if significant noise is present. And a test was defined to assert the presence of a linear texture.

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Comparison of Methods for Measuring the Presampled Modulation Transfer Function

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Introduction The presampled modulation transfer function (MTF) is the MTF before digitisation of the image has been undertaken. Measurement of this function can be used for assessing digital images as it removes the problems associated with aliasing effects. There are a number of different methods for measuring the presampled MTF, including slit[1] and edge[2] techniques and it is useful to understand the practicalities and uncertainties associated with each method.

Methods The presampled MTF was determined for a number of digital systems, including computed radiography (CR) and direct digital radiography (DDR). The presampled MTF was measured using the slit and edge techniques for each system. Both the slit (20 μm) and edge were produced from tungsten sheet, 2 mm in thickness, with accurately milled edges. The edge and slit were both imaged at a small angle of between 1° and 6° to the horizontal and vertical axes. Composite line and edge spread functions were produced using IDL (Interactive Data Language, Research Systems Inc.) and the presampled MTFs were calculated.

Results Preliminary work shows that the slit and edge methods are equivalent. Results will be presented on the various digital systems tested. This is work in progress.

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Mammography Doses in Ireland

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It is required by the Medical Exposures Directive 97/43/Euratom that Diagnostic Reference Levels (DRLs) be established for all radiological examinations. To date DRLs for Mammography have not been established in Ireland. There are approximately 41 licensed Mammography Systems in Ireland, the majority of which are conventional systems. The study itself provides a measurement of the Mean Glandular Breast Dose from 13 systems. The results were obtained as detailed in the European Guidelines, using a standard 4cm thick phantom. *[European Protocol on Dosimetry in Mammography].* Results of this study allow a comparison of Mammography doses in Ireland and facilitates a comparison with EU DRLs. They may also assist in establishing DRLs in Ireland and play a major role in the implementation of the requirements of the Medical Exposure Directive.