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WORKS IN PROGRESS ABSTRACTS

WIP-T-01

A Simple and Fast Analytic Approach to Dwell-time Calculations for Vaginal Irradiation with Ir-192 HDR

P. Lee *, Alexian Brothers Cancer Care Center, Elk Grove Village, Illinois

A simple and fast analytic approach to the dwell-time calculations for vaginal irradiation with Ir-192 high dose-rate remote afterloaders has been formulated. This approach is based on the following two facts: first, in postoperative vaginal irradiation, isodose surfaces are prescribed to 5 mm tissue depth to cover vaginal stump of 2.0 - 4.5 cm in length. Since typical vaginal applicators are 2.0 - 3.0 cm, the prescription isodose surfaces are only slightly elongated and resemble ellipsoids. Secondly, the dosimetry of Ir-192 is dictated by a very simple inverse square distance factor due to the fact that, in tissues, the attenuation of the primary beam is nearly compensated by the scattered photons. By assuming that the isodose surfaces are elliptic, the inverse square distance factors from any point on the elliptic surface to the point sources on the long axis can be calculated. For a linear array of N sources, N points near the center of the elliptic surface are chosen to set up N linear dose-distance-factor-dwell-time equations with N dwell-times as the unknowns. A simple matrix technique involving matrix inversion is used to calculate the N dwell-times from the prescription dose, the inverse square distance factors and a dosimetric multiplicative constant. The dwell-times for 9 most common combinations in vaginal irradiation with 2.0, 2.5 and 3.0 cm applicators, and 5, 7 and 9 steps were calculated. The isodose surfaces for the 4 most extreme cases out of the 9 examples are presented to demonstrate the efficacy of this analytic approach.

WIP-T-02

Clinical Implementation of AAPM TG-43 Report on I-125 Seed Implant

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The traditional dose rate term (rads cm^2/hr mCi) is widely used for I-125 sealed seed implants for many clinical situations. The difference between dosimetry generated using this value and that generated using values recommended by the AAPM Task Group 43 (TG-43) is about 10%. This paper describes methods for implementing recommendations of TG-43 for the Seattle I-125 transperineal prostate seed implant method. The prescribed matched peripheral dose (MPD) may need to be adjusted after implementation. Current commercially available I-125 sealed seeds model 6711 (Amersham Healthcare) and model MED 3631-A (North American Scientific, Inc.) are studied. Data comparisons are made for the CMS Modulex RTP and ADAC Pinnacle RTP systems. Although air kerma strength can not be used directly in older RTP systems, it is not difficult for most RTP systems to employ many of the recommendations of the TG-43 Report. This is true because of TG-43=s term for the Aair kerma rate constant@ has units (cGy cm^2/hr mCi) similar to the traditional dose rate term. Today, using a point source as an approximation for a line source is accepted for most I-125 brachytherapy. In the future, however, air kerma strength and line sources may be required in RTP systems to more accurately meet the recommendations of the AAPM TG-43 Report.

WIP-T-03

Comparison of Different Commercial Treatment Planning Systems for Cesium 137 Source Modeling

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Purpose: To compare different commercial treatment planning systems for Cs-137 source modeling.

Methods: Based on the vendor's specifications of Cs-137 source internal structure, CMS Focus utilizes a two-compartment version of the Sievert Integral dose computation model. Dose rate tables were generated from the CMS Focus module for each Amersham and 3M Cs-137 source. Testing for each source was done against Monte Carlo calculations. Dose rate data from CMS for a symmetric source were calculated and compared with those of Krishnaswamy. MMS applies the assumption that the Cs-137 source consists of a cylinder centered symmetrically on a radioactive line source. MMS utilizes a one dimensional pathlength (Sievert Integral) algorithm for dose calculation, and this was tested against V. Krishnaswamy's published dose rate data. Dose rate data from MMS was also compared with Monte Carlo data.

Results: The CMS Focus model for the Amersham source differed from Monte Carlo results on average by 0.9%. The 3M source resulted in an average difference of 0.7%.. The symmetric source data for CMS focus differed from V. Krishnaswamy's data by an average of 4.7%. MMS data differs from V. Krishnaswamy on average by 4%. MMS data differs from Monte Carlo results by 21% at certain along distance.

Conclusion: CMS Focus's two compartment Sievert integral model provides an accurate 2-D dose rate calculation while maintaining the calculation efficiency of one-dimensional integration. Different source-specific dose distributions should be used for clinical treatment planning.

Key Words: Cs-137 source, two compartment Sievert integral, 1-D pathlength sievert integral

WIP-T-04

CT Autorecognition of Source Positions for Prostate Post-Implant Dosimetric Evaluation

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A post-implant dosimetric evaluation of I-125 or Pd-103 implants of the prostate is a necessary but time-consuming procedure. Typical implants require 40 to 100 or more sources, depending on the size of the target volume and the source distribution. Minimizing the number of sources (and needles) simplifies the procedure and the post-implant evaluation. The efficiency of the post-implant evaluation has been improved using autorecognition of the source positions. Source signatures are detected by software based on CT number and size of enhancement. The autorecognition software uses a 5x5x5 voxel kernel generated using a 0.5 mm sigma gaussian shape. The CT number search threshold value may be adjusted to identify within a few sources of the correct number. Source identification is checked by comparing the AP result to an AP radiographic film taken at time of CT. Sources suspect of misidentification are investigated by mouse clicking the source position on the AP region-of-interest digitally reconstructed radiograph (ROIDRR) and checking the source position on orthogonal ROIDRRs. Misidentified positions may be immediately deleted. Additional sources may be added by identifying its position on two of the three orthogonal views.

Source positions are identified to the nearest voxel, equivalent to the axial CT pixel resolution and CT image step interval. The accuracy of source position identification is being evaluated using 1 mm and 3 mm CT step intervals.

WIP-T-05

Dose Distribution for an Intravascular Brachytherapy Ir-192 Source

S. Chiu-Tsao *, S. Liprie, C. Soares, H. Tsao, L. Harrison, Beth Israel Medical Center, NY, NY

It is important to accurately assess the doses delivered to intima, media and adventitia in intravascular brachytherapy for restenosis. Hence, precision dosimetric studies for an Ir-192 source (model SL-77HS, Vascular Therapies, a division of US Surgical Corporation) have been performed using GafChromic film (model 55-2) measurements and Monte Carlo calculations with MCNP4A code. The experimental films (in a stack form) were irradiated by the Ir-192 source at contact geometry in a Solid Water phantom. The film calibration curve was established by exposing multiple calibration films (one at a time) to an Nucletron HDR Ir-192 source for known doses in the same phantom. The spatial resolution achieved using a scanning laser microdensitometer for the film was finer than 0.2mm. The MCNP4A

calculations were carried out for both photon and beta contributions using F6 and F8 tallies, respectively. The resolution was 0.1 and 0.2 mm in the radial and longitudinal directions, respectively. The dose rate values were obtained in the plane through the source's longitudinal axis. We have found good agreement in the results from the film measurements and Monte Carlo calculations. We present the overlay of (1) the isodose curves and (2) the plots of dose rate Vs. radial distances from the two methods. Along the perpendicular bisector of the source, the dose rates are 17.9, 8.55, 5.86, 4.60, 3.78, 2.99 and 2.69 cGy/sec-Ci at radial distances of 1 to 4 mm at 0.5 mm increments. The results are very useful for treatment planning calculations of intravascular brachytherapy.

WIP-T-06

Dosimetric Measurements of a New I-125 Brachytherapy Source

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A dosimetric study of the North American Scientific I-125 seed model MED3631-A has been performed in Solid Water using XV and GafChormic films. Fourteen ready-pack XV films were exposed in contact with the seed, from 2 to 23 minutes, to cover a range of exposures. A set of XV calibration films were irradiated at 1 cm from the seed center to obtain the H&D curve. Nine pieces of GafChromic film were irradiated in contact, with irradiation times ranging from 5 hours to 42 days. A previously obtained response of GafChromic film to I-125 was used to convert optical density to dose (Chiu-Tsao et al Med. Phys. **21**(5) 651-657 (1994)). The radial dose function g is obtained for distances between 0.04 cm and 2 cm using the GafChromic film, and out to 9 cm using XV film. The anisotropy functions for radial distances up to 9 cm were obtained at 10 degree intervals using the XV film data. The point source approximation anisotropy factor was obtained data from both types of film. All data are compared with TLD measurements (R.E. Wallace and J.J. Fan, private communication) as well as with Monte Carlo calculations (see work in progress abstract by J. Shih et al.). Comparison with 6702 I-125 model data is also made.

WIP-T-07

Dosimetric Parameters of a new I-125 seed

J. Shih *, S. Chiu-Tsao, St. Luke's-Roosevelt Hospital Center and Beth Israel Medical Center, NY, NY

A study was performed to determine the TG-43 dosimetric parameters of Mentor IoGold ^{125}I seed (model MED3631-A) for use in treatment planning. This seed (outer dimension of 0.8 mm D X 4.5 mm L) contains four ^{125}I ion-exchange resin spheres together with two gold markers. Its titanium cladding is similar to Medi-physics 6702 seed, except that the end weld is much thinner. The active length of the source is 3 mm. Monte Carlo calculations for a single IoGold seed in water were done using MCNP 4A code. Doses from 0.045 cm to 8 cm in the radial direction and up to 7 cm in the longitudinal direction were calculated at various spacing. Doses at regions adjacent to the seed (as close as 0.45 mm) are useful for dosimetry in intravascular brachytherapy. The results indicate that the dosimetry of this new seed is similar to 6702 seed, but it exhibits less anisotropy than either 6711 or 6702 seed. The dose rate constant is 0.95 cGy/h·U versus 0.93 for 6702 seed. The radial dose function, g(r), stays slightly higher at distances greater than 1 cm. The biggest discrepancy occurs at 4 cm from the center of the seed. The g(r) at this point is 0.583 and 0.511 for IoGold seed and 6702 seed, respectively. The anisotropy function, $F(r,\theta)$, are presented for use in conventional and intravascular bachytherapy.

WIP-T-08

Early Performance of a New Miniature X-ray Needle for High Dose Rate Brachytherapy

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One of the problems with current brachytherapy techniques is the availability, transport, and storage of radioactive seeds and the associated radioprotection concerns for staff, patients, and the public. This problem could be eliminated with the development of X-ray "needle" technology for brachytherapy applications where source placement can be confined along straight lines. X-ray "needles" generate low-energy X-rays at the tip of a long narrow needle, producing quasi-isotropic point dose distributions. In the device we investigated (TITAN Corporation, New Mexico) X-rays were generated by accelerating thermionic electrons from a filament down a needle (3.5mm outer diameter, 11cm long) toward a stainless steel hemispherical target at the needle tip. The radiation dose rate varied from 0cGy/min to 50cGy/min at 1cm from the needle tip, depending on the kilovoltage (up to 62.5kVp) and current (up to 300mA). This dose rate is expected to be improved to 500cGy/min with a water-cooled second generation device. The half-value layer of the X-rays was measured to be 2.5mm in water. GAFchromic film was also used to measure the dose distribution at the needle tip and to assess the feasibility of replacement of brachytherapy seeds. At present, the dose rate instability and lack of electron optics limits the use of this prototype clinically. By overcoming these shortcomings, this device could become a valuable alternative to radioactive brachytherapy seeds in the treatment of brain, prostate and head and neck tumours.

WIP-T-09

Effects of Random Seed Placement Error on Brachytherapy Seed Implants

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Effect of Gaussian random seed placement error on dose distribution and target coverage in brachytherapy seed implants is investigated. Relationship between variance of random seed placement error and variance of point dose has been established. When a point of interest (POI) is not close to any seed locations, measured with respect to seed active length, and the variance of random seed placement error is small compared to the minimum distance between seed locations, this relation is linear and the linear coefficient depends only on seed locations. Knowing average and variance of POI's dose, we can predict the probability that the POI's dose is in a specific dose range. With the average POIs doses and their corresponding variances in hand, we can compute the minimum probability that any POI inside the target will get MPD as a function of the variance of random seed placement error. This probability is the expected target coverage probability which is very important to the success of any brachytherapy seed implant. This work will give tolerance levels of seed placement error in brachytherapy seed implants for certain target coverage requirements.

WIP-T-10

Measurement of Transit Time of a High Dose Rate Remote After-loading Brachytherapy Source

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Quantification of transit time of high dose rate (HDR) remote after-loading brachytherapy source is important[1,2] both for accurate treatment planning and for quality assurance checks. In this investigation, an HDR-1000 well ionization chamber and a precision electrometer are used to measure the transit time of the Ir-192 source of the Nucletron Micro-Selectron HDR unit. The values of the total charge generated during source dwelling at the end of an endobronchial catheter inserted into the chamber, and during the source travel to this position from another location at a distance of 0.5 to 10 cm were measured. A linear regression analysis of the charge as a function of time was made. The transit time was calculated from the ratio of the charge intercept and the slope of the straight line. Preliminary results of the present investigation are the following. The values of transit time were found to be 0.1, 0.36 and 0.58 seconds for source movement of 0.5, 5 and 10 cm respectively. These values indicate that the transit time per cm decreases with distance of travel. The source speed increases as the distance between two dwell positions is increased. Values of transit time for other inter-dwell distances will be presented. The suitability of this procedure for routine quality assurance check of the transit time will be discussed.

1. P. V. Houdek et al., Int. J. Radiation Oncology Biol. Phys. 24, 795 (1992).
2. K. T. Bastin et al., Int. J. Radiation Oncology Biol. Phys. 26, 695 (1993).

WIP-T-11

Potential Use of I-131 in Intravascular Brachytherapy

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Purpose: This investigation was undertaken to study the dosimetry of low activity I-131 encapsulation in liposome for potential and save use in intravascular brachytherapy.
Methods: The coronary artery was modeled as a hollow cylinder made of soft tissues with inner diameter 3mm and outer diameter 4mm with length 15 mm . For photons, the conventional exposure factor 2.185 R cm**2/(mCi* hr), F factor 0.97 cGy/R and an attenuation coefficient of 0.106 cm**2/g were used to do the dosimetry. For beta particles and electrons, an average energy of 0.1834 MeV and an absorption coefficient of 40 cm**2/g were used. The dosimetry was done with the schema developed by Lovinger,Berman and Berger and a point source function developed at the Johns Hopkins for radio-immunotherapy.
Results: With 10 uCi of I-131, dose rates at the outside vessel wall (2 mm from the center) were 0.24 and 17.04 cGy/hr from photons and electrons respectively. With the physical half life 8.04 days and an estimated effective half life 3 days, the cumulative dose would be 1792 cGy. Therefore in order to deliver 15 Gy to a 0.5 mm thick wall , only 8.37 uCi of I-131 is needed.
Conclusions: With a low activity , it looks that I-131 encapsulation of I-131 in liposome can be a potential useful isotope for intravascular brachytherapy in terms of shielding and radiation safety.

WIP-T-12

Prostate Seed Needle Autoradiograph

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An autoradiograph procedure has been developed in order to verify the placement of radioactive seeds loaded in needles for insertion in the prostate. I-125 or Pd-103 seeds along with required spacers are loaded in needles according to the treatment plan.

A sterile paper is stretched flat over a ready-pack of 25cm by 30cm verification film. Taping the four corners onto a counter top stretches the paper. The loaded needles are laid out on the film in the order they appear in the plan. The exposure is for five minutes for CEA film or 10 minutes with Kodak V film. The needles are then transferred into their corresponding template locations of the operating room shielded box. After the film is developed, each needle image is compared with the plan.

Out of 45 implants, autoradiographs revealed mispositioned or missing seeds in 7 cases. The needles with errors are reloaded correctly and returned to the shielded box.

The autoradiograph is used to perform a seed count and serves as a permanent record of the seeds used in each needle of the implant.

The autoradiograph takes only a little extra time and is an excellent quality assurance tool for procedures using pre-loaded needles.

WIP-T-13

Prototype CT and MR Compatible Scannable FSD Applicator

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A feasibility study was performed to identify suitable materials for the construction of a CT-MR compatible Fletcher-Suit-Delcos (FSD) applicator. Current FSD applicators are made of steel and hence are not suitable for either computed tomography (CT) imaging or magnetic resonance (MR) imaging because of streak artifacts and patient hazards, respectively. A search for appropriate materials was undertaken with the following conditions.
CT and MR compatibility requires that the applicator 1) be distinctly identifiable on the reconstructed images, 2) be visualized as a lower pixel value than the surrounding tissue or tumor, and 3) create no artifacts that interfere with the interpretation of the images. In addition, the material must 1) be rigid and when broken should not fragment, 2) be capable of withstanding multiple sterilizations, 3) not significantly attenuated by radiation, 4) easily be manipulated and not bulky, and 5) be easily machined with conventional machining tools.

A material that meets these requirements is polysufone, a polymeric material classified as high-strength thermoplastic. It is made from the reaction of disodium salt of bishenol A with sulfone in dimethylsulfoxide. It has a density of 1.24 g/cm^3.

A prototype of this applicator has been constructed and tested. It consists of two oviods and three tandems. Each of these components was constructed by milling a solid polysufone material for each half and glued together to form the instruments. CT and MR images of the applicator demonstrated excellent performance. The construction of this prototype applicator and its associated difficulties will be discussed.

WIP-T-14

The Determination of Surface and Depth Doses to Water from Sr-90 Sources

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There is little known about the depth doses very close to brachytherapy sources. Knowledge of this information is especially important for intravascular brachytherapy sources where the point of interest is 2-4 mm from the source. Measurements of the beta dose rate on the surface of a NIST calibrated Sr-90 opthalmic applicator using an extrapolation chamber have been made. The rate of change of current vs air gap in the extrapolation chamber for air gaps of 0.12 mm - 0.25 mm in 0.033 mm increments was measured. These measurements determined the average dose rate over the central 10 mm of the source, whereas NIST determines the dose rate of the central 4 mm. The 10 mm measurents were converted to the central 4 mm by multiplying by the ratio of the average pixel value for each area from a film scan of the source. The results of these measurements, after some corrections, are consistent with those from NIST. The measured dose rate was 0.43 +/- 0.09 Gy/sec compared to the NIST result of 0.43 +/- 0.05 Gy/sec. This measurement method will be used to measure the beta dose rate in different phantom thicknesses.

WIP-T-15

The Impact Of Calcified Plaque And Stainless Steel Stent On The Dose Distribution From 32P, 90Y, And 188Re Solid Wires For The Inhibition Of Arterial Restenosis

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Our goal was to find how much the calcified plaque and stainless steel stent affect the dose distribution from β-emitters (^{32}P, ^{90}Y, and ^{188}Re). The magnitude of dosimetric perturbation was investigated using the ITS Monte Carlo code. The sources were modeled as uniformly loaded radioactive cylinders 0.3 mm in diameter by 3 mm long. Only the ^{32}P was encapsulated with 0.05 mm thick titanium. The plaque was considered as cartilage bone. The compositions of cartilage bone, stainless steel stent , tissue and blood were taken from literature. A Palmez-Schatz stent was used to calculate the percentage area of strut relative to whole area of the stent to model the stent pattern mathematically. The percentage area of strut was 37.7%. Dose with a mesh stent was mathematically modeled from with and without a pipe type stent. considered as water for the Monte Carlo calculation. When there was 1-mm plaque in the artery, the radiation transmission was 58%, 78%, and 68% for ^{32}P, ^{90}Y, and ^{188}Re, respectively. When there was 2-mm plaque in the artery, the radiation transmission was 21%, 49%, and 40% for ^{32}P, ^{90}Y, and ^{188}Re, respectively. The radiation transmission was calculated as ratio of dose with plaque and dose without plaque. The thickness of a Palmez-Schatz coronary stent was 0.076 mm (0.003"). At 0.5 mm from the stent surface, radiation transmission for the stent was 88.3%, 87.5%, and 87.9% with ^{32}P, ^{90}Y, and ^{188}Re, respectively. The stent reduced dose by 13% compared to that without the stent.

WIP-T-16

Comparison of A Proposed Multiple-seed Assay Method with The Single-seed And Batch Assay Methods for I-125 Seeds in Ultrasound-guided Prostate Implants

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A simple five-seed assay method was proposed. A commercial well ion chamber with NIST-traceable calibration constant was used for single-seed assay. A batch seed holder was used for batch assay. For the five-seed assay, another single-seed holder was modified such that all five seeds are loaded in central region of the plastic holding tubing. Compared to the seed in standard seed holder, relative chamber responses for the five seed positions were 0.993, 0.993, 1.000, 1.001 and 0.977, respectively. Averaged value of 0.993 was assigned to all five positions. Consequent assays with single-seed and five-seed methods indicated only 0.4% difference. When a dummy seed replaced an active seed, 20% reduction in charge was found, indicating that the proposed assay method can detect a dead seed. Compared to single-seed method, the five-seed method is equally reproducible with greatly reduced assay time due to the five-time higher charge collected. Compared to batch assay, the five-seed method can detect dead seeds and is more reliable due to its higher reproducibility in its assay geometry. Seed assays employing all three methods in our clinics will be presented and discussed in more details. AAPM TG40 states that, for brachytherapy, ideally every (i.e., 100%) loose seed should be calibrated but, due to large number of seeds used in prostate implants, it then recommends that 10% of seeds be calibrated. The proposed five-seed assay facilitates the implementation of the "10%" practice; it makes the "ideally 100%" statement a more realistic and realizable QA practice in seed assaying.

WIP-T-17

The Effect of Edema on the Dosimetry of Prostate Seed Implant

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Edema resulting from injury by insertion of needles during the implant procedure causes the prostate to swell. As the prostate heals, its volume shrinks. At the same time, the radioactivity of the seeds also decays. The interaction of these two kinetics (another process being the change in prostate volume due to cell killing) affects the delivery of radiation to the prostate tissue. For post-implant dosimetric evaluation of the implant, a CT scan is usually required. Clinically, the delay of this CT study scan from the time of procedure is variable – from one day up to two weeks. A dose calculation based on this delayed CT scan is performed and assumed to be the initial dose rate which when multiplied by the average radioactivity lifetime gives the total dose. Clearly, this approach produces errors due to the varying prostate volume and decaying radioactivity. This study is done both analytically and with clinical data. Upon making assumptions about the magnitudes and time-evolution of the edema, equations relating the dosimetric errors with the CT scan time-delay, half-lives of the radioactivity and edema, and the magnitude of the edema are derived. Also, optimum time-delay is calculated which will give minimum dosimetric errors. Clinically, a series of patient CT scans can be done at different delay-times, and the corresponding dose distributions are integrated over time to get the total dose distribution. A time-evolution modeling of the edema derived from the actual CT imaging studies can be used for future dosimetric studies.

WIP-T-20

Clinically Shaped Fields: Relative Outputs for Varian multileaf Collimators and Tray-mounted Cerrobend Blocks

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PURPOSE: The purpose of this study was to compare output factors for fields using multileaf collimators (MLC) versus fields using tray-mounted blocks. Unlike previously reported studies, the present comparison involved a sampling of MLC fields actually used on patients.
METHODS AND MATERIALS: A total of 21 different fields from 16 patients were compared by casting Cerrobend blocks from the same films that had generated the original MLC shapes. Output measurements were made on a Varian 2300CD (26 leaves per side) in solid water for 6 and 20 MV at SAD (100 cm) and at two depths: 5 cm (d_5) and the clinically prescribed depth ($d_{clinical}$). All measurements were taken under the central axis unless the shaped field was skewed off-axis or the beam was split. Several cases were repeated on a Varian 2100CD (40 leaves per side) MLC.
RESULTS: For the 21 cases studied, the average overall MLC factor (MLC reading block reading) was 0.9952, with a standard deviation (sd) of 0.0024 (see Table I and Figure 1). The 2100CD results agreed 0.2%. Table III shows the data broken down in terms of clinical category at prescribed depth and energy (overall clinical average: 0.9957, sd 0.0022).
CONCLUSIONS: The overall average and the total clinical average MLC factors (0.995-0.996) both agree with previous literature, which used abstract or generic field shapes. Further investigation of the data from this study may find a correlation between MLC factor and percent open field.

WIP-T-21

Radioactivity Observed in Patient Following Teletherapy with 25 MV X-rays

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Following a four field treatment for prostate cancer with 25 MV X-rays, a patient reported for work at a nuclear power plant and received a routine whole-body radioactivity scan approximately one hour after treatment. This scan revealed a significant quantity of 511 keV gamma rays of unknown origin. Additional scans at times from 0.5 to 3.5 hours following subsequent treatments continued to demonstrate measurable amounts of 511 keV radiation with intensity that decreased with time after treatment. Measurements at the hospital with a Geiger counter at 4, 14, and 24 minutes after one treatment gave readings of 0.15, 0.02 and 0.02 mR/hr immediately over the treatment area. Background was approximately 0.01 mR/hr. The count rate from a Lucite block which was exposed to approximately 3000 cGy in 2 minutes was recorded for a period of 2.5 hrs and revealed two decay components with half lives of about 2 and 20 minutes which are consistent with positron emission from ^{15}O and ^{11}C which result from (X,n) reactions in ^{16}O and ^{12}C. The radioactivity in the patient is evidently due to the same source even though the $^{12}C(X,n)^{11}C$ reaction has a threshold of about 20 MeV. This may be a source of additional but unknown dosage in the volume ir

WIP-T-22

The Investigation of the Relative Surface Dose from Asymmetric Fields Using Enhanced Dynamic Wedges

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The relative surface dose from symmetric open fields has been thoroughly studied. Enhanced Dynamic Wedges have been developed to allow treatment of larger X-ray field sizes with diverse wedge angles. It has been established that reducing the source to surface distance, increasing the field size and oblique incidence increases the relative surface dose. This investigation compares the relative surface dose for asymmetric fields with that from Enhanced Dynamic and conventional wedges. A Markus chamber was used to map the relative surface doses in various off-axis positions. The added width capability of Enhanced Dynamic Wedges causes an abundance of head scattered electrons and low energy X-rays to be incident on the surface of the patient. The use of bolus or other types of compensation may then not be necessary to increase surface dose.

WIP-T-23

Variation of Dose with SSD on an Orthovoltage Unit

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We have recently commissioned a new orthovoltage unit (Pantak Therapax-300). It is generally assumed that the output of an orthovoltage unit can be calculated using an inverse square law (ISL) correction, when the unit is used to treat with a gap between the treatment cone end and the patient's skin. We

have found that both the in-air and surface dose-rates do not follow ISL but fall off more rapidly with distance from the cone end.
These effects are observed when using closed-end cones. Open-ended cones more closely follow the ISL. We are analysing this data in terms of a model that assumes that the deviation from the ISL is due to additional radiation scattered from the treatment cone end.
We will present comprehensive data on the variation of dose-rate as a function of distance from the treatment cone, for various measurement conditions, together with the results of our analysis.
In recent years, several publications have presented beam characteristics of this machine[1,2,3] . None of these papers describe this effect. We recommend that centres using this unit measure output factors as a function of distance from the cone end.

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3. Dose Characteristics of a New 300kVp Orthovoltage Machine, M.L.Butson et al, Aust. Phys. & Eng. Sci. in Med. 18 (1995) 133-138

WIP-T-24

Beam Optimization Utilizing Equivalent Uniform Dose

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Ideally intensity modulated beams should deliver a uniform dose distribution, at the prescribed level, within the tumor. However, the competing demand of low dose outside the tumor makes this difficult. For a non-uniform dose, it is desirable that the optimization process arrives at a solution which gives an equivalent uniform dose (EUD) equal to the prescribed dose. Two optimization methods are presented here.

The first method updates beam intensities using ratios of desired dose to current dose, with importance weights for each tissue. A high tumour importance can mean dose immediately outside the tumor reduces too slowly. Alternatively a lower tumour importance with a higher prescription dose (D_p) can be used. A low dose near the edge of the tumor can be compensated for by a higher dose further from the edge For this purpose, D_p can be adjusted to maintain a specified EUD. EUD versus D_p is only slightly sub-linear, so after optimizing, the gradient of EUD vs. D_p can be used to update D_p.

The second method is to update the beam intensities by comparing the EUD at each stage of the procedure to the required EUD. Instead of using the whole-tumour EUD, EUD along the axis of each beam element is used.

Both methods have been applied to a clinical situation The first situation shows a reasonably flat distribution across the tumour. The second distribution is less homogeneous with a high dose to the centre of the tumour and a lower dose to the edge.

WIP-T-25

Effect of Bone on the Depth Dose Distribution from 22Cf Source in Total Soft Tissue Equivalent Phantom

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In this work the effect of implantation of bone in a Total Soft Tissue equivalent solution (TST) on the Depth Dose Distribution (DDD) of fast and slow neutrons and gamma rays components from 252Cf source positioned in the center of a cubic shape perspex phantom, 30 cm side is studied. The effect of bone type, thickness and geometry on the DDD is also investigated. Solid state nuclear track detector CR-39, and TLD's types LiF-600 and LiF-700 were used for measuring the fast and slow neutrons and gamma doses respectively. Radiation contours for the DDD were plotted.

The results indicated the build up of both gamma and slow components of the dose in the TST while the fast neutron component was decreased. However, at locations close to the implanted bone the fast neutron component was relatively increased. Moreover, the results indicated also that the type and position of the implanted bone play an important role on the radiation contours.

WIP-T-26

Injuries Induced by Low Level Doses of Fast Neutrons On Rats

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The aim of the present work is to find out the injuries that may occur to the blood and the blood generating system from exposures to very low level doses of fast neutrons. Male rats were exposed to different doses (0.1 mSv to 3 mSv) of fast neutrons from AmBe source. The direct and late effects of neutrons on the blood of the animals were investigated through the measurements of the dielectric relaxation and mobilities of the hemoglobin molecules, osmotic fragility and solubilization of the RBC's membrane and some serum enzymatic and hormonal activities such as GPT, GOT, insulin, T3, T4 and testosterone.

The results indicated that there were changes in the relaxation time (tao), dipole moment (mu) and electrophoretic mobility of the Hb molecules extracted from exposed animals to the neutron doses demonstrated. Moreover, the RBCs membrane proved to be also injured. Furthermore, the levels of the enzymes and the hormones studied were all markedly changed. Late effect studies for the animals, 45 days post-irradiation, proved the injury of the blood generating system and gonads responsible for the studied hormones and enzymes and no repair was noticed.

WIP-T-27

A Fast Head Scatter Calculation Algorithm for Static IMRT

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Head scatter calculations for static IMRT require time consuming ray tracing from a calculation point's eye view (CEV) for several points and segments. Speed gains (about a factor of 15 to 30) are realized by modeling the scatter as an extended source consisting of a set of strips perpendicular to the beam (z axis) and parallel to the leaf motion direction (x), and by storing the scatter contribution in a table whose row and column numbers are the strip location (y) and length (from $x = 0$), respectively. The range of strips seen (y_{min} to y_{max} locations) from the line $y = y_c$, through each polygon formed by the leaves, is determined based on the yz plane projections of y jaws and the first and last open leaf pairs in the polygon. For each calculation point x_c on the line $y = y_c$, the left and right edges of these visible strips are determined by performing calculations based on xz plane projections for only a subset of leaves, rather than ray tracing through all leaves. The subset is determined based on the minimum right leaf position and the maximum left leaf position of the leaves forming the polygon. The scatter contribution is determined from the table entries for the left and right edges of the strips. This calculation treats all collimating structures with their full thickness and divergent edges to avoid overestimating scatter. This work is funded by Siemens Medical Systems.

WIP-T-28

A Finite-size Pencil Beam Dose Calculation Model for Intensity-Modulated Radiation Therapy

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In intensity-modulated radiation therapy (IMRT), some optimization algorithms require as input the knowledge of the dose contribution from a beamlet to a dose point. After the optimization, the dose distribution inside the patient's body needs to be evaluated using the optimized beam intensity profiles. For this purpose, a finite-size pencil beam (FSPB) photon dose calculation model has been developed. The pencil beam kernel is represented with a sum of three Gaussian functions. Then the FSPB kernel, which is the integration of pencil beam kernel over its cross section, is expressed with a closed analytical form. The amplitude and standard deviation for each Gaussian function are determined by fitting the calculated broad beam dose distributions with measured data. The measured data used for fitting includes the phantom scatter factors, percent depth dose, and off-axis ratios, so that the fitted pencil beam kernel is physically realistic. As long as the parameters are

determined, the dose distributions for irregularly blocked and compensated fields can be calculated in the unit of cGy, by simply superimposing the FSPB kernels with various weights. The model has been verified by comparing the calculation with measurement for regular shaped open fields, typical blocked fields and wedged fields. Good agreement has been observed. The major advantages of the present model are that the algorithm can be commissioned using standard broad beam data and the dimension of FSPB can be adjusted during the dose calculation process.

WIP-T-29

A Practical Total Scatter Correction Factor for Dose Rate Calculations for Asymmetrically Collimated Photon Fields

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Recent literature[1-6] indicates that there is no absolute consensus on an approach to the dosimetry of asymmetric photon fields. This investigation presents a correction factor for total phantom scatter (Khan's $S_{c,p}$)[1] that accounts for perturbations in dose due to asymmetric field effects. Our factor, coined here as the Output Factor Ratio (OFR) is derived from a simple mathematical fit of the ratio of asymmetric to symmetric total scatter factors for square fields of 4x4 cm^2, 10x10 cm^2, and 20x20 cm^2 and for off axis distances (OADs) of 0 to 15 cm at d_{max}. All measurements were made at the center of open fields. The effect of asymmetrically collimated fields on TMR was also investigated. The ratio of OCR at depth to the OCR at d_{max} was shown to be highly effective in converting central axis TMRs to asymmetric field TMRs. An augmented dose rate formula is presented here that implements the off-axis TMR (OATMR) and OFR to obtain improved accuracy in asymmetric field dose rate calculations. Calculated dose rates of asymmetric rectangular fields using this formula and clinically available beam data average 1% difference from measured dose rates at depths of up to 20 cm with OADs up to 13 cm. A table of asymmetric field correction factors for monitor unit calculations can easily be generated from a few ionometric measurements and a PC spreadsheet program with this method.

WIP-T-30

Calculation of Head Scatter Factors at Isocenter or at Center of Field for Any Arbitrary Jaw Setting

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The purpose of this work is to calculate the head scatter factors for any arbitrary jaw setting by using two different semi-empirical methods. The head scatter factor at the center of field (COF) for any arbitrary jaw setting can be defined as $H_{COF}(X_1,X_2,Y_1,Y_2,r)=D^{air}{}_{COF}(X_1,X_2,Y_1,Y_2,r)/[D^{air}(5,5,5,5,0)*OAR(r)]$, where X_1, X_2, Y_1, and Y_2 are the jaw positions; r is the distance between COF and isocenter (IC); OAR(r) is the Off-Axis-Ratio; $D^{air}{}_{COF}(X_1,X_2,Y_1,Y_2,r)$ is the dose in air measured at COF; $D^{air}(5,5,5,5,0)$ is the dose in air measured at IC for the 10x10 cm^2 field . In certain clinical situations, doses are prescribed at IC instead of COF for asymmetric fields. In these cases, head scatter factors should be determined at IC. It is found that the head scatter factors at IC for asymmetric fields ($H_{IC}(X_1,X_2,Y_1,Y_2)$) are lower than $H_{COF}(X_1,X_2,Y_1,Y_2,r)$ for the same jaw setting by up to 3%. The values of $H_{IC}(X_1,X_2,Y_1,Y_2)$ and $H_{COF}(X_1,X_2,Y_1,Y_2,r)$ for a variety of jaw settings were measured using a miniphantom of 3-cm diameter for a 6 and a 18 MV photon beams. An equivalent square formula, derived presently at the source plane for any jaw setting, was used to calculate $H_{COF}(X_1,X_2,Y_1,Y_2,r)$. The calculation and the measurement agree within $\pm$1% ($\pm$0.5% for most of clinical situations). To calculate $H_{IC}(X_1,X_2,Y_1,Y_2)$, we have generalized the Day's "quarter-field" method, i.e., $H_{IC}(X_1,X_2,Y_1,Y_2)=[H(X_1,X_1,Y_1,Y_1)+H(X_1,X_1,Y_2,Y_2)+H(X_2,X_2,Y_1,Y_1)+H(X_2,X_2,Y_2,Y_2)]/4$. We found that the calculation and the measurement agree within $\pm$0.8% for the beams.

WIP-T-31

Dosimetric Evaluation of Water-Bolus for Irradiation of Extremities in the Management of Kaposi's Sarcoma

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High-energy photon beams and a large parallel-opposed field arrangement are often used to deliver a homogenous dose throughout the extremities in the management of Kaposi's sarcoma. The extremity was immersed in water contained in a commercially available plastic wastebasket. The water serves as a bolus that conforms to the curvature of the extremity and effectively eliminates the skin sparing effect. A polystyrene block was placed at the floor of the wastebasket to ensure that the extremity was encompassed in the radiation field.

This study examined the dosimetry of these field arrangements for different photon beam energies, 4 MV, 6 MV, 10 MV, and 24 MV. The wastebasket has a dimension of 24 cm x 38 cm x 43 cm was placed at the isocenter. Field size of 30 cm x 30 cm was employed.

The result showed that the dose distributions are more homogeneous with higher photon beam energies. The maximum doses in the treatment field is 17% more than the isocenter dose for the 4 MV photon beam, 10% more than the isocenter dose for the 6 MV photon beam, and 7% more than the isocenter dose for the 10 MV and 24 MV photon beams. The lower energy photon beams show distinct hour-glass effect phenomenon with constriction of isodose lines in the middle of the treatment volume. Photon beam energy higher than 10 MV would be preferable for the treatment of superficial lesions of the extremities immersed in water bolus contained in a typical wastebasket sized container.

WIP-T-32

Monte Carlo Calculated Electron ROFs and Dose Distributions for Siemens MXE

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As part of a program to implement electron Monte Carlo treatment planning clinically, we have performed a comprehensive set of measurements of dose distributions and relative output factors for our Siemens MXE electron beams. Measurements were made at 5, 10 and 14 MeV for field sizes ranging from 2x5 to 15x15 cm squared, and at SSDs of 100, 110, and 120 cm. The Monte Carlo calculations are performed using the EGS4 based codes BEAM for the simulation of the treatment head, and DOSXYZ for the simulation of the water phantom. There is good agreement (3%) between the measured and calculated percent depth doses including extended SSD. The profiles also agree well, with the exception of the measured horns on the 15x15 field. For this case the calculated profile is 4% lower that the measured data. The calculated dose per electron incident on the scattering foil (relative to the 10x10 value) agrees with the measured relative output factors to 5%, except for extreme cases (ROF near 0.25) where there is an 11% discrepancy. This is attributed to a change of monitor chamber sensitivity with jaw opening. If the output factors are normalized to the open field at 100cm SSD for a given applicator (instead of to the 10x10 field) the agreement is generally 2% or better except for the extreme cases where agreement is better than 4 %.

WIP-T-33

Monte Carlo Method for Commissioning Electron Beams

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A new paradigm for electron beam commissioning is to calculate the entire beam data set using Monte Carlo computational techniques. The purpose of the present work is to demonstrate that this is a viable alternative to the standard method of measuring beam data. Using the EGS4/BEAM code to simulate electron transport through the treatment head in sequence with the EGS4/DOSXYZ code to calculate dose distributions in water, results have been shown to match a select measured data set to within 2-3%. The present

study uses the code to calculate depth-dose curves, profiles at several depths, output factors, and air gap factors for a clinically useful range of applicator-insert combinations for the 9-, 12- and 20-MeV electron beams produced by a Varian 2100C linear accelerator unique to M.D. Anderson. To date, beam data have been calculated for a 12-MeV beam with 10x10 cm^2 and 25x25 cm^2 applicators. Calculated depth dose curves and profiles for the open 25x25 cm^2 applicator and the 10x10 cm^2 applicator with inserts down to 2x2 cm^2 agree with measured data to within 2% of D_{max} (or 2 mm in regions of high dose gradient). Calculated output factors (relative to the open cone value for each applicator size) agree with measured data to within 1% except for very small fields. Calculated air gap factors are within 2% of measured data. The agreement between calculated and measured data supports the hypothesis that Monte Carlo calculations can reliably produce electron beam commissioning data for the Clinac 2100C.

This work is supported in part by Varian Oncology Systems sponsored research agreement SR97-015.

WIP-T-34

Monte Carlo simulation of kV X-ray units: a comparison of BEAM/EGS4 and MCNP4b2

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To obtain accurate information on dose distributions in water for kilovoltage X-rays, the photon spectrum, planar fluence and the angular distribution of the photons at the collimator exit have to be known. The only practical way to obtain this information is by Monte Carlo (MC) simulation. In this work, two MC codes, BEAM/EGS4 and MCNP4b2, were used to build realistic models of two X-ray tubes. The tungsten target, exit window, collimator and additional filtration were taken into account. The contribution to the characteristic radiation from electron-impact ionization and from the photoelectric absorption of bremsstrahlung photons was studied. Firstly, calculated and measured photon fluence spectra and HVL values for a Philips MCN410 tube (Gent) were compared for several anode voltages and additional filtrations. Secondly, the Siemens Stabilipan Th300 X-ray tube at ICR (Sutton) was modeled and HVLs and dose distributions in water were compared with measurements for several clinical X-ray qualities. The scattered radiation from the clinical applicators was included.

A comparison of BEAM/EGS4 and MCNP4b2 shows that neither MC code adequately handles the production of characteristic X-rays, and that MCNP4b2 needs much longer calculation times for comparable simulations. Despite the incomplete physical modeling of characteristic photon production, the results show that the MC models of the X-ray tubes are able to reproduce photon spectra in air, HVLs and depth-dose distributions in water.

WIP-T-35

RTDS-A Radionuclide Imaging and Therapy Dosimetry System

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An integrated PC-based radionuclide imaging and therapy treatment planning and dosimetry system (RTDS) has been developed. The overall design of RTDS is based on an object-oriented model. It includes two major components: a database subsystem and a calculation module subsystem. The database developed under Microsoft Access stores and organizes the clinical data. Calculation modules developed with Microsoft Visual Basic are the calculation processes needed to estimate the final absorbed radiation doses. These consist of four modules: imaging-processing module, quantitative activity calculation module, modeling module and dose calculation module. The imaging-processing module handles image display and processing. The quantitative activity calculation module estimates the radioactivities in organs. Here, the user is provided with three options of algorithm: the generally used conjugate view method, our CT assisted matrix inversion (CAMI) method and quantitative SPECT. The modeling module handles the modeling of biological data. Both simple curve fitting routines and compartment model are incorporated into the system. The dose calculation module estimates absorbed radiation doses. Two dosimetry models are developed: the generally used MIRDOSE3 algorithm and our Monte Carlo assisted voxel source kernel (MAVSK) algorithm which uses the patient CT volume to perform real-time (calculation under 1 minute) patient-specific dosimetry analysis and generate dose volume histograms. All final and intermediate dosimetry results are saved to and tracked by the database. RTDS will greatly improve the quality of dosimetry analyses for radionuclide imaging and therapy, especially for radioimmunotherapy. It provides a user-friendly software program and standard format for internal emitter absorbed dose estimation.

WIP-T-36

Dosimetry for Ultraviolet Phototherapy

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Ultraviolet phototherapy is used to treat patients with psoriasis. Although great attention is paid to the drug regime for these patients, the dosimetry of the ultraviolet radiation used for treatment is not well defined. This is of concern as a long-term complication of this type of therapy is radiation induced melanoma. Dosimetry is determined from only the output of one bulb and patient dimensions and attenuation are not considered. In most cases, there is no defined calibration or quality assurance procedures carried out on these devices.

Information will be presented about the spatial distribution of doses to patients. A calibration and quality assurance protocol will also be presented. This work may be of assistance in providing a more scientific basis for the treatment of these patients.

WIP-T-37

Estimation of Radiation Exposure From Radionuclide Therapy Patients Using an Interactive Computer Simulation

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We have developed a PC-based computer program that permits the rapid estimation of exposure to hospital personnel from patients undergoing therapeutic or diagnostic radionuclide procedures. The patient's environment (hospital room, imaging suite) is visually modeled using 2-D scale floor plans. The virtual "patient" or "meter" can be placed anywhere within the environment scene using "drag/drop" techniques, and the exposure rate computed at any point in the scene using an algorithm which models the "patient" as a self-absorbing cylinder with uniform distribution of radioactivity. The height and mass of the cylinder may be varied, accommodating differences in body habitus. The "meter" or "patient" may be moved through the scene along an arbitrary path and the time-integrated exposure calculated. Exposures consequential to tasks by nursing and nuclear medicine staff may be rapidly estimated without assuming fixed occupancy factors. A retrospective validation study using data for 68 I-131 patients indicates an overestimation of the six-foot exposure rate by factors of 1.04 +/- 0.16 and 1.24 +/- 0.22 for oral iodine and MIBG respectively. This is likely due in part to the underestimation of tissue absorption inherent in the uniform cylinder model, with the variability related to the use of a single "male" or "female" body habitus for all patients. Estimations of exposure based on simulations of brief nursing tasks, such as taking vital signs and meal tray delivery, are comparable to actual measurements using personal dosimeters.

WIP-T-38

An application of GafChromic MD-55 film for 68 MeV clinical proton beam dosimetry

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The purpose of this study is to explore the use of GafChromic MD-55(RC) film for 68 MeV clinical proton beam dosimetry at Crocker Nuclear Laboratory, UC Davis. Several strips of RC films 2.5" x 2.5" in dimension were irradiated at a depth of 18.2 mm corresponding to the middle of 24 mm spread-out-Bragg peak (SOBP). The films were irradiated to a proton dose in

the range of 0.5 Gy to 100 Gy. The nominal doses were measured by .1cc EG&G chamber. The beam profiles were also measured at the middle of 24 mm SOBP. The Bragg peak and SOBP were measured by using a wedge shaped phantom made of lucite. The exposed films were analysed using He-Ne laser densitometer. The calibration of the dose response of RC film showed(after background subtraction) a linear increase of optical density (O.D)with dose from .5 to 100 Gy. The uniformity of O.D over a single sheet of film showed a variation of ± 2%. The distal-fall off between 90% to 20% as measured from Bragg-peak was 1.3 mm and FWHM of 3.6 mm as compared to diode measurement in water of 1.5 mm and 5 mm. In conclusion, Gafchromic MD-55 film may be a useful and rapid detector for dose measurement and quality assurance program of proton beams.

WIP-T-39

Air Kerma Strength Measurements for Low Dose Rate Brachytherapy Sources

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In 1990 the University of Wisconsin introduced an interpolative method of determining the air kerma strength of High Dose Rate (HDR) Ir-192 sources. Charge is collected in an ionization chamber at seven consecutive distances from a stationary source suspended in free space. A series of correction factors and an exposure calibration factor (N_x), interpolated from NIST traceable beams, are applied to calculate air kerma strengths. This technique is referred to as the "seven distance technique." We have extended this technique for the measurement of Low Dose Rate (LDR) sources. The air kerma strengths of two Cs-137 sources and two Ir-192 LDR seeds were measured with this technique. A comparison with the values obtained from conventional calibration techniques was made. The results show agreement to within 5% of values obtained with other established calibration techniques (all measured at one distance). With this proof of principle established using LDR sources for which primary NIST calibration exists, the work can be extended to include additional LDR sources that will require primary calibration. Iodine seed air kerma strengths measured with this technique will be presented, as well as a discussion of measurements of new sources which lack primary NIST calibration.

WIP-T-40

Calibration Accuracy in Gel-dosimetry

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A new method of calibrating gel dosimeters is presented which has higher accuracy than presently used methods, and requires less gel. Two test-tubes of gel (inner diameter 2.5cm, length 20cm) are irradiated separately with a $10x10cm^2$ field end on in a water bath, such that the characteristic depth-dose curve is recorded in the gel. The calibration is then determined by fitting the depth-dose data measured in water, against the measured change in relaxivity with depth in the gel. Increased accuracy is achieved in this simple depth-dose radiation geometry by averaging the relaxivity at each depth. Calibration data over the full range of dose (1.6-10 Gy) is obtained by irradiating one test-tube to 10Gy at dose maximum (Dmax), and the other to 4.5Gy at Dmax. The new calibration method is compared with a 'standard method' where 5 identical test-tubes of gel were irradiated to different known doses between 2 and 10Gy. The percentage uncertainties in the slope and intercept of the calibration fit are found to be lower with the new method by a factor of about 4 and 10 respectively, when compared to the standard method and published values. The gel was found to respond linearly within the error bars up to doses of 7Gy, with a slope of 0.233 ± 0.001 sec^{-1} Gy^{-1} and an intercept of 1.106 ± 0.005 sec^{-1}.

WIP-T-41

Comparison of Dosimetry Calibration Services at the NRCC and the NIST

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In March of 1998, three transfer ionization chambers were used to compare the air-kerma and the absorbed-dose-to-water calibration factors determined by the National Research Council of Canada (NRCC) and the National Institute of Standards and Technology (NIST). The ratios between the NRCC and NIST calibration factors were 1.0061 ± 0.0003 and 0.9936 ± 0.0003 in the cases of the air-kerma and the absorbed-dose-to-water calibrations respectively. Both of these results are within the stated overall uncertainties in the primary standards of the two laboratories. The stability of the ion chambers' responses was demonstrated since the calibrations done at NRCC after those at NIST agreed within 0.04% with those made prior to the NIST calibrations. Consistency of both standards at the two laboratories is indicated by the observation that the calibration factors of one of these ion chambers showed a uniform change of 0.13% in the present study compared to the previous one in 1991. This is an important comparison in light of the anticipated emphasis expected for absorbed-dose-to-water standards as a result of the TG-51 protocol for dosimetry. It represents the first comparison of the recently declared Canadian absorbed-dose-to-water standard based on the NRCC sealed water calorimeter.

WIP-T-42

Evaluation of a Dosimeter for Intra-Operative Radiation Therapy

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Intra-operative radiation therapy (IORT) is presently conducted in a number of departments world-wide. Unlike with conventional external-beam therapy, pre-treatment in-vivo dosimetry is not routinely used, because conventional diode dosimetry systems are poorly suited to such use and because treatments are delivered in a single fraction.

A dosimetry system based on a MOSFET detector (Thompson & Nielsen Electronics Ltd., Ontario, Canada) has been evaluated for its suitability for use in IORT. Its potential use would be to measure a small test dose of 10% of the prescribed dose to verify calculations and setup. A dosimetry system with several detectors was obtained and the sensitivity, reproducibility and linearity of response were determined under conditions simulating IORT. Electron beams of 6, 9 and 12 MeV were used, with doses between 150 cGy and 3,000 cGy per exposure. Additional tests were devised to measure extracameral signal as well as the effects of shielding, bolus and sterile tubing.

The dosimetry system was found to exhibit sensitivity, linearity and reproducibility consistent with the requirements of IORT. The standard deviation of multiple exposures was less than 3% of the reading. The device deviated roughly 8% from linearity at very high dose levels, but was within 3% at dose levels that might be used for preliminary verification. No degradation of performance was seen resulting from the use of shielding, bolus or sterile tubing. The dosimeters did not perturb the dose distribution significantly.

This work supported in part by Thompson & Nielsen Electronics Ltd.

WIP-T-43

Improved Precision To Photon Energy Spectrum Reconstruction Algorithm

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Knowledge of the photon energy spectrum emanating from a medical linear accelerator can improve the accuracy and delivery of radiation therapy. An elegant and promising method of photon energy spectrum reconstruction is being modified to give higher precision. The original method is based on narrow beam attenuation and requires the accurate measurement of transmission in the range of 100 to 1 percent[1]. The numerical reconstruction process is highly dependent upon the accuracy and precision of these

measurements. Scattered radiation, electrometer noise and leakage, and a detector response that is energy dependent will introduce errors into the transmission measurements that will affect the reconstructed spectrum. These sources of error are especially problematic at low transmission levels and strongly affect the high energy end of the reconstructed spectrum. Numerical techniques designed to improve the precision in the reconstruction will be presented. It is believed that this increase in precision will make the reconstruction process less sensitive to the scatter and other errors in the measurements. These techniques, which are easy to implement, will be demonstrated on analytic spectra of realistic shape. One of these techniques has been used on the transmission measurements of a 4 MV beam from a Varian 600C accelerator.

References:

1. Catala, P. Francois, J. Bonnet, and Ch. Scourarnec. *Reconstruction of 12 MV bremmstrahlung spectra from measured transmission data by direct resolution of the numeric system AF=T*. Med. Phys. **22**(1) 3-10. (1995).

WIP-T-44

Measurement of radiotherapy x-ray skin dose on a curved surface

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Assessment of radiotherapy breast patient skin dose is important to ensure that sufficient dose is given to reduce the probability of a near surface recurrence while a low enough level is maintained for acceptable cosmesis. To simulate a chest wall breast treatment a half cylinder solid water phantom of 7.5 cm radius was irradiated with 6 MV x-rays using a 20 x 20 cm^2 field at 100 cm SSD.

A continuous surface dose profile was obtained from 0^0 to 180^0 around the circumference of the phantom. Dosimetry results obtained using radiochromic film (effective depth 0.11 mm) included 28% (of D_{max}) at 0^0 beam entry position, 58% at 90^0 oblique beam position. The experiment was repeated using 1 cm of bolus. By combining the results and normalizing to a prescribed mid point dose of 50 Gy from two tangent fields, using an alternate bolus on bolus off regimen, the skin would receive 36.8 Gy at 0^0 incidence and 46.4 Gy at 90^0 incidence.

Surface dose results were also obtained using extra thin TLDs (effective depth 0.14 mm) of 30% at 0^0, 57% at 90^0, and a Radfet detector (effective depth 0.5 mm) of 43% at 0^0, 62% at 90^0. Note the Radfet has a greater effective depth in the rapidly increasing dose build-up region.

Note as the circumference of the phantom is traversed the SSD increases and hence there is a fluence fall off, this is offset by the increase in skin dose due to surface curvature.

WIP-T-45

Verification Method of Lung Density Correction used in a Commercial IMRT algorithm used for treatment of Lung Cancer

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For treatment of localized lung tumor, 6MV photons, with intensity modulated radiation therapy (IMRT) using dynamic arc is used at our center. The leaf intensity profiles and treatment plans are generated using a "Corvus" treatment-planning computer. This paper presents the measurement method used for verifying the accuracy of the density correction algorithm used for computing. The calibration of the CT # with known densities was obtained by taking a CT scan of the RMI phantom 465-1248. The calibration curve was linear within the range of CT# from –1000 to 1500. The IMRT plan generated using a Rando chest phantom using TLD chips, placed at locations with in the clinical target volume located inside the lung and at lung tissue outside the target. Three sets of readings were taken using 3 different arc lengths, used at our clinic. The measurement results indicated that the computer calculated dose was less than the measured values by 3 to 4%. The measured value without using density correction resulted in an over dose of 16 to 20 % depending upon the arc length used. The comparison of the patient treatment dose distribution will be done using film and TLD measurements in a Rando phantom and the results will be presented.

WIP-T-46

Evaluation of the Photon Beams Produced by a Dual Photon Beam Linear Accelerator

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Dosimetric measurements have been made for the 6-MV and 15-MV photon beams of a Mitsubishi EXL-17DP linear accelerator. The dosimetric data presented for both beams include selected central axis percent depth doses (PDD), selected central axis tissue maximum ratios (TMR), field size correction factors, beam flatness, beam symmetry, beam quality, wedge factors, and measured beam output consistency. The 6-MV beam central axis nominal accelerating potential was found to be 5.5 ± 0.3 MV and the 15-MV beam central axis nominal accelerating potential was found to be 12.8 MV ± 0.3 MV. Beam flatness variation values were found to vary with gantry angle from 2.9% to 4.2% for the 6-MV beam and 1.6% to 2.6% for the 15-MV beam. Mirror symmetry variation was found to vary over gantry angle from–2.0% to +4.2% for the 6-MV beam and –4.6% to +2.6% for the 15-MV beam. The beams' percent depth doses were found to be within manufacturer's specifications.

The 6-MV and 15MV beams of the EXL-17DP and a Clinac 2100C were found to have d_{max} values, 10 cm PDD's, and 20 cm PDD's that are essentially equal, therefore clinically, the beam energies are identical.

Keywords: radiotherapy, linear accelerator, dosimetry, depth dose, tissue-maximum ratio

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WIP-T-47

Natural Convection In Sealed Water Calorimeters Operated at 22 oC

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The accurate measurement of absorbed dose to water in photon and electron beams using primary standards is essential in the implementation of absorbed dose based protocols such as the AAPM - TG51. At NIST, as well as at NRC (Canada), water calorimetry forms the basis of the disseminated ^{60}Co absorbed dose standards. In order for water calorimetry to work reliably, convective motion in water must be either eliminated (e.g., by operating at 4 °C) or proven to lead to predictable calorimeter operation. In a sealed water calorimeter, high purity water is contained in a sealed vessel inside a large tank. In addition to controlling water purity, the vessel is conventionally assumed to act as a convective barrier. However, experiments show that post-irradiation drifts in high energy photon and electron beams are significantly different at 22 °C compared to 4 °C, and this may lead to extrapolation, and thus dose, errors of 0.5 - 2% depending on the dose profile. Numerical heat transfer calculations show that at 22 °C, fluid velocities of up to 10 mm/min outside the sealed vessel combined with modest velocities inside the vessel explain the observed post-irradiation drifts as well as the differences in measured dose. Heat transfer from the vessel wall to the measuring point in the NIST calorimeter, which is operated at 22 °C, leads to a 0.5% overprediction in measured temperature rise. This result is in agreement with intercomparisons showing a similar discrepancy between the NIST and NRC disseminated dose at ^{60}Co.

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WIP-T-48

An Approach to Propagating Uncertainties in Radiation Therapy

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The radiation therapy process involves many steps including patient imaging, target volume and critical organ delineation, beam selection, dose calculations, treatment simulation, dose prescription, and treatment delivery. Each step of the process has its own inherent uncertainties which contribute to the overall uncertainty in treatment outcome. In this work, we develop a macro Monte Carlo-type approach to propagate the uncertainties through the entire process. With this methodology, we can perform uncertainty analysis on individual stages, or multiple stages, and ultimately on the entire process and isolate which sources of uncertainty are critical to outcome (i.e. sensitivity analysis). We categorize uncertainties into: (1) absolute dose at a reference point (e.g. isocentre), (2) normalized dose distribution (%), (3) location and volume of target volume and critical organs, and (4) biological response parameters. A model is then created for each of the four categories. Instead of simulating each step of the actual process to propagate these uncertainties, we propose to classify the uncertainties from each step of the process into one or more of the above categories. Uncertainties from the different steps may then be *summarized* into "effective" or "composite" distribution functions of the parameters in the models. Finally, uncertainties are propagated across the four categories to yield the outcome data. We present an example in one dimension to illustrate how the concepts behind this approach may work in more complex clinical situations.

WIP-T-49

Customised Compensation by Dynamic Multileaf Collimation

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A technique to provide customised compensation for individual patient contours has been developed as an extension of current irregular field MLC treatment techniques, enabling the introduction of IMRT to the clinic without radical changes in working practice. Customised compensation is produced using dynamic MLC, where differential exposure, rather than differential attenuation, is used to modulate the intensity of the beam.

Compensators are designed by calculating the 2D input intensity map required to produce a uniform dose distribution at depth, using a dose calculation model which determines primary and scatter components separately. The initial approximation to the required intensity distribution is then passed to a software module known as the 'interpreter' which calculates the dynamic leaf trajectories needed to deliver the compensated beams. Finally, a dose calculation to the specified plane at each angle based on the calculated MLC leaf positions is performed. Any differences between the required and calculated deliverable dose distributions can be used as the basis for iteration.

The software has been tested for a variety of surface shapes and irregular field outlines and has been shown to effectively compensate for extremely demanding test shapes, producing uniform dose distributions at depth under highly irregular surfaces. The calculation of leaf trajectories and the delivery of the intensity modulated beams by the Elekta MLC in its dynamic mode have produced encouraging results, giving confidence in the move towards clinical implementation of customised compensation by dynamic MLC.

This work is supported by Elekta Oncology Systems.

WIP-T-50

IORT Apparatus Design Improvement Through the Evaluation of Electron Spectral Distributions Using Monte Carlo Methods

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Clinically used IORT electron beam characteristics may vary with respect to typical external beams due to the decrease of lateral scatter equilibrium and the addition of the IORT apparatus itself. Additionally, chamber size effects may lead to inaccurate measurements of the changes in electron beam characteristics. The causal components of these beam characteristics are often difficult or impossible to measure using experimental techniques. For this reason, and for potential design improvement, the electron beams were modeled using the OMEGA/BEAM Monte Carlo software for radiation transport. The IORT electron beam characteristics of the Varian Clinac 1800 were studied for nominal 6, 12, and 20 MeV electrons and 1 through 4 inch diameter flat-end applicators. The characteristics studied include electron energy spectra, percentage depth dose curves and cross-plane profiles. Evaluation of the electron energy spectra demonstrates the utility of modeling for the purpose of design improvement by indicating a potentially inadequate aluminum base plate thickness. It was found that by increasing the thickness of the aluminum base plate of the main attachment, the dose at d_{max} outside the primary field could be reduced from approximately 9% to 1% of maximum.

WIP-T-51

Patient Throughput Maintained Using a Full Field Multileaf Collimator (MLC) Leaf Width 1.0cm for Shaped Fields as Small as 2.0cm

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The limiting factor in the control of the prescribed isodose using an MLC is the leaf width. A solution is to reduce this width multiplying the leaves to a number that would be mechanically unsound, another is the use of an expensive block cutting device for small fields. An alternative is the already available small MLC (typically 10cm square) with smaller blade widths which attaches to the treatment head as required. This method assumes that the only high resolution required is around the central axis and that the field will not exceed 10cm. Also if Quality Assurance is carried out each time the device is fitted the patient throughput must reduce. Clearly these add on devices are designed for small field work such as stereotactic and head/neck regimes. An example where high resolution is required on a part of the field that is outside the available 10sq field is a Nasopharynx treatment where high resolution/control is required around the eye. We have been using techniques to improve contour control using a full size MLC since 1993. We have recently been reviewing our stereotactic and head/neck regimes and now have a need for small shaped fields, for both normal treatment and dose escalation. From our original work we have managed to extend our methods, enabling a shaped MLC field to be created as small as 2.0cm, using a conventional MLC with a blade width of 1.0cm at the isocentre. There are no field joins and the treatment time is not increased.

WIP-T-52

The Development of Target Eye View Maps for Treatment Planning

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Three dimensional conformal radiotherapy allow the use of tightly conformed multiple noncoplanar beams. However, visualizing the spatial relationships between the target volume and adjacent critical structures are not always obvious, easy or intuitive. Tools such as Beam's Eye View (BEV) aid this process and often prove very useful. The Target Eye View (TEV) map was developed as a functional extension of BEVs.

The TEV map is created by calculating the BEV for every possible gantry and table rotation angle. For each possible BEV, the amount of overlap between the PTV and each critical structure is determined. This information is presented in a left handed Mercator spherical map projection, where each point's colour indicate the amount of overlap between the critical structure and the PTV. In the composite TEV map, angles where the PTV can be covered with little critical structure overlap are blue while significant overlap angles are red.

The TEV map can also be converted from spherical coordinates into treatment coordinates with the gantry angle on the abscissa and the table angle on the ordinate. The accuracy of the TEV maps have been cross checked with confirmatory BEVs generated by a 3D planning system.

The TEV map provides an useful tool in choosing appropriate treatment angles for developing a treatment plan. Its potential use in beam optimization will be examined in the future.

WIP-T-53

Application of Generalized LQ Model to Extended Treatments Regiments

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The generalized LQ model theory with an exponential time factor is applied to standard fractionations and a prolonged series of mini treatments. A new parameter ÒTime to Tumor Regrowth (Trg)Ó is defined as the period in which an irradiated but incompletely eradicated tumor regrows to its original size before it was irradiated. This time Trg is calculated based on the LQ model and compared for the two treatment regimens. The modelÕs theoretical predictions are analyzed to inquire if they can be clinically useful in treatments of some selected patients.

These calculations suggest that for some incurable tumors a series of mini treatments separated by intervals Trg can maintain a patients health status and quality of life at an acceptable level, for a longer period of time compared to traditional five fractions per week treatment regimens.

WIP-T-54

Commissioning, Clinical Implementation and Quality Assurance of Siemen's Virtual WedgeTM

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The Manitoba Cancer Treatment and Research Foundation has recently commissioned and approved Siemen's Virtual Wedge™ for clinical use on one of its linacs. Virtual wedge offers several advantages over traditional physical wedges - the handling of cumbersome physical wedges and associated safety concerns are eliminated; a greater number of wedge angles are possible with virtual wedge; and field size limitations are much less stringent with virtual wedge than with physical wedges.

In this work, we present our experience with commissioning, clinical implementation and quality assurance of Siemen's Virtual Wedge™. Commissioning measurements show that 1) Virtual Wedge factors are within 2% of unity; 2) percentage depth doses are within 1% of open beam data; 3) the gantry angle dependence of wedge profiles is similar to open beam profiles; 4) the output of wedged fields is linear with delivered monitor units within 1%; and 5) wedged beam profiles can be modeled similar to a physical wedge and follow a well defined equation to facilitate modeling of arbitrary wedge angles. Quality assurance results indicate the wedge profiles are very stable over time. Day to day variations of two points measured along the wedge gradient direction are within 1.5%.

WIP-T-55

Online Quality Assurance of Linear Accelerator With Electronic Portal Imaging System

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On-line geometrical quality assurance system using Electronic Portal Imaging System (OQAuE) is developed. EPID system is networked to Pentium PC in order to catch the acquisited image from EPID. Geometrical QA, including Light-Radiation field congruence, Collimator rotation axis, and Gantry rotation axis can be easily performed by graphical user interface (GUI) software.

Geometrical Quality Assurance of A Linear Accelerator (CL/2100/CD, Varian, USA) equipped with the EPID (Portal Vision, Varian, USA), which is networked to OQAuE, was used to evaluate this system. Light-Radiation field congruence tests by center of gravity analysis showed 0.2~0.3mm differences for various field sizes. Collimator (or Gantry) rotation axis for various angles could be obtained by superposing 4 shots of angles. The radius of Collimator rotation axis is 0.2mm for upper jaw collimator and 0.1mm for lower jaw. Acquisited images for various gantry angles were rotated according to the gantry angle and actual center of image point obtained from collimator axis test. The rotated images are superpositioned and analyzed as same method as Collimator rotation axis. The radius of Gantry rotation axis was 0.3mm for Anterior/Posterior direction (gantry 0° and 170°) and 0.7mm for Right/Left direction (gantry 90° and 260°).

Image acquisition data analyses are faster than conventional method and the results are objective and accurate within a milimeter range. The OQAuE system proven to be a good tool for the geometrical quality assurance of linear accelerator using EPID.

WIP-T-56

Quality Assurance regimes on Multileaf Collimators, Speed, Reproducibility and therefore Frequency increased by the use of Customised Test Equipment.

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Multileaf Collimators (MLCs) have as many as 40 pairs of independantly driven leaves. In order to use the device to its potential the user must know that each leaf is performing correctly. Daily Quality Assurrance (QA) along with methods to assess the MLC accurately and quickly are required. Customised Tools and Protocols are needed to maintain an acceptable standard. We have developed a range of tools that allow a speedy and accurate assessment of the field. Each leaf can be assessed for positional accuracy and light field distortion. Radiaton/Light Field alignment per individual leaf is easilly checked over the complete field by use of a customised tool. A check film may be taken in the same time as a normal film for a standard head. The field centre and one other reference point are marked, on a shaped field using all the leaves, the film is then exposed and processed. The resulting image is placed on a transparent test tool illuminated via a light box. Each leaf radiation/light field alignment is then quickly checked. Collimator skew referenced to the primary collimator (Varian), offset fields, all basic setup functions, and MLC parameters are routinely check on a frequent basis. One tool allows the complete MLC setup to be assessed including backup diaphragms (Philips). Replacement cameras (Philips) and light field sources may be replaced and setup using the reference fields. All levels of staff are now able to participate in the QA regimes as there are definative tools for each stage.

WIP-T-57

The Efficient use of a Commercial System for Daily Therapy Beam Quality Control.

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A Gammex RBA-5 radiation beam analyzer in conjunction with Argus Software's Quality Control Information Management (QCIM) system is being used for daily monitoring of the seven therapy beams produced by an Elekta SL15 linac. The system acquires a lot of information with minimal effort. Relative output, beam symmetry and flatness, and an energy ratio that requires consecutive exposures with different thickness buildup plates are recorded in a computerized database. The acquisition of the energy ratio data would require fourteen trips into the treatment room. In lieu of constructing an automated buildup plate changer, a protocol was devised to minimize footsteps between exposures. This implies that the commercial software would not be able to calculate energy ratios for all beams. Methodology was developed which allows QCIM to calculate three of the seven energy ratios. The remaining four are calculated "off line" using EXCEL 97 that reads a data file exported by the Argus software. Monthly, quarterly and yearly trends of all quality parameters for each beam can be displayed on one spreadsheet. Baseline data is shown in order to document when RBA-5 reference levels have changed. On the annual review reports additional information such as ionometric calibrations, RPC results, and the relative setting of digital information, which maintains the absolute output of the beam, can be documented easily and displayed graphically.

WIP-T-58

A Control System for Computer-assisted Daily Patient Setup

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While computer-controlled accelerators and digital radiography systems promise the potential for precise daily evaluation and correction of patient setup, little progress has been made in the integration of these components. As a result, online setup adjustment remains a cumbersome task limited in accuracy and speed. In order to address these issues, a modular control system is being developed and implemented to integrate the subsystems of a "target-of-the-day" patient setup system. Components have been developed to measure patient position and correct this position using a computer-controlled treatment couch with six degrees of freedom (tilt and roll capability has been integrated within the treatment couch). The control system is based on an interactive client/server model and will allow components to be integrated in a semi-automated fashion from within an in-house Computer Controlled Radiotherapy System (CCRS). Redundant position feedback systems within the treatment couch allow for precise computer-controlled setup. The repositioning accuracy is limited not by the repositioning system (estimated 1 mm translation and 0.03 degrees rotation) but by the tool used to measure setup error. This system is being evaluated for daily localization of the patient (using bony landmarks) or the tumor (inferred from the location of implanted radiopaque fiducial markers).

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WIP-T-59

Comparison of Computer-Controlled Versus Manual Setup Adjustment in Radiotherapy

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The use of portal imaging for online setup correction is currently under investigation at many clinics. Current standard practice for application of the corrective action involves relaying information to the therapists, who then manually adjust the treatment couch. This study investigates the potential benefit of automated computer controlled treatment couch adjustment for online setup correction. An in-house computer-controlled radiotherapy system (CCRS) with control of couch position was modified to communicate with a portal imager control computer. Transformations describing setup error, determined from alignment of portal and reference images, are sent directly to the CCRS to modify couch position automatically the next time a therapist enters the treatment room. The time between the acquisition of the portal image and the next treatment or verification event (adjustment time) was measured for eighteen patients. The accuracy of each procedure was determined retrospectively from the residual error of patient position at the time of treatment following setup measured using an image acquired during treatment. The adjustment time was measured for seven automated and eleven manual setup adjustments. The average adjustment time per patient was 95 seconds faster using automated repositioning. Analysis of seven automated and nine manual adjustments studied yielded an average 1.1 mm increase in accuracy for the automated cases. Additional patients will be analyzed to ensure the statistical significance of this study.

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WIP-T-60

Initial Performance Evaluation of a Clinical Prototype Active Matrix Flat-Panel Imager for Radiotherapy Imaging.

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Following about 10 years of research and development of active matrix flat-panel imaging technology for application in external beam radiation therapy imaging[1,2], the first practical clinical prototype based on this technology has been implemented in our clinic. The imager is an early commercial prototype (Varian Associates, Palo Alto, CA) based on an array of 512x512 amorphous silicon, thin-film-transistor+photodiode pixels, with a 508 μm pixel pitch giving ~26x26 cm^2 detection area. The imager provides indirect detection of incident radiation by means of a converter (Cu + Gd_2O_2S:Tb phosphor) overlying the array. The integration of this imager on a Varian 2100 CD therapy machine was achieved using components of a commercially available scanning liquid ionization chamber system (Portal Vision, Varian Associates) including a robotic arm attached to the treatment gantry. While imager readout is synchronized to the radiation delivery providing fluoroscopic operation, the imager provides single frame images consisting of the average of a number of consecutive frames. Signal properties measurements (including quality assurance parameters that impact on clinical utility) along with patient images from a wide variety of anatomical sites will be shown.

[1]Antonuk et al. "Demonstration of megavoltage and diagnostic x-ray imaging with hydrogenated amorphous silicon arrays". Med. Phys. 19(6):1455-1466; 1992.

[2]Antonuk et al. "Initial performance evaluation of an indirect-detection, active-matrix flat-panel imager (AMFPI) prototype for megavoltage imaging". Accepted for publication in Int. J. Rad. Onc, Biol, Phys. (May 1998).

WIP-T-61

Delivery of IMRT Utilizing the NOMOS Corvus TPS and a Siemens PRIMUS Accelerator with MLC.

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The steps needed to implement IMRT in a free-standing radiotherapy facility will be outlined. Because this project required the interface of three systems recently developed and distributed by their vendors, problems and delays were encountered. These will be presented. In the first phase a local area network was set-up. This network provided the means for the seamless transfer of data between all nodes on the system. The Corvus treatment planning system was then interfaced to a Siemens Somatom-Plus Spiral CT scanner. All CT images were reformatted though a DICOM Merge Box before download to the Corvus TPS. After the completion and approval of a final IMRT plan, the multiple MLC fields with corresponding MU settings and gantry angles were pushed to an IMPAC record and verify system. After proper data transfer to IMPAC was verified all treatment parameters were then downloaded to a Siemens PRIMUS accelerator equipped with MLC and Simtech Software. The final phase of the project involved verifying the correct download and delivery of the IMRT plan.

WIP-T-62

Linear Accelerator Beam Characteristics and Dosimetry for Low Monitor Unit Treatment Delivery

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Respiratory gated radiotherapy or multiple static field intensity modulated radiotherapy may necessitate the delivery of a greatly reduced number of monitor units (MU) compared to conventional treatments. 10-15 MU are delivered during the first two seconds of treatment when the accelerator dosimetry is stabilizing. An examination was made of the ionization chamber response and beam profile characteristics for linear accelerators from three manufacturers for 6-18 MV x-rays. Measurement of dose versus MU shows that the accelerator's ionization chamber responds in a strongly linear fashion ($y = mx + b$), but with an offset which can be a significant fraction of 1 MU. On one manufacturer's accelerator capable of delivering beam sequences, delivery of 50 segments of 1 MU resulted in 40% greater dose than delivery of 1 segment of 50 MU. Modification of the accelerator's dosimetry system to allow correction for chamber offset as well as linearity reduced this offset error to less than 1%. On the other machines, no facility for offset correction exists. Beam profiles were obtained at a depth of 10 cm in solid water for 30x30 cm^2 collimator settings using Kodak V film for exposures of 1-100 MU and were compared to profiles obtained in water using a commercial scanning

system. Results show that as the number of MU is decreased, the beam profiles become more rounded resulting in a degradation of beam flatness of several percent.

This work is supported, in part, by a sponsored research agreement from Siemens Medical Systems.

WIP-T-63

Viability of a Cobalt-60 Tomotherapy Unit

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Tomotherapy is a recent proposal for practical conformal radiotherapy in which a radiation source mounted in a CT-like ring gantry is rotated about the patient during treatment. Complex three dimensional dose distributions can be achieved by modulating the intensity of the radiation as the source rotates about the gantry and the patient is steadily advanced through the plane of the gantry. The potential for linear accelerator based tomotherapy has been shown by others, and a prototype clinical device is currently under development.
In this paper the feasibility of a clinical tomotherapy unit utilizing Cobalt-60 as the radiation source is studied. Two major factors are analysed: the radiation dose properties and the mechanical and structural issues. The suitability of multiple Co-60 radiation beams for tomotherapy is assessed using computer calculations based on in-house planning and simulation software and on measurements performed using a simple, first generation, tabletop CT jig mounted on a conventional clinical Co-60 unit. The mechanical properties of various ring gantry configurations with single and multiple sources are also presented. The designs are based on a unit able to deliver clinically useful doses in an acceptable time frame from single or multiple Co-60 sources. Masses and static stresses have been determined for units utilizing three different shielding materials. In all cases the results are well within the endurance limits of a proposed steel gantry.

WIP-T-64

Extension of CadPlan Algorithm to Model the Dose Distribution Under a Motorized Wedge

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The CadPlan treatment planning system takes into account the dose distribution in the non-wedge direction under a wedge field by modeling the thickness of the wedge as an effective thickness of water and using the open field profiles at this extended depth to give part of the off axis ratio (OAR). This model has been shown to work well for a Siemans Mevatron KD-2 Linac. However, the motorized wedge of the Elekta (formerly Philips) accelerators is tapered off axis and designed to give a very flat dose profile in the non-wedged direction. The model assumes that the wedge has a uniform construction in the non-wedge direction and so cannot model the off axis dose for the motorized wedge. For the 4 MV beam of a SL75/5 accelerator this leads to a 4% overestimate and a 7% underestimate of the OAR under the thin and thick edge of the wedge, respectively. For the 6 and 18 MV beams of a SL20 accelerator the model underestimates the OAR by more than 10% under the thick end of the wedge. We have corrected the model for the 6 MV and 18 MV beams by modifying the CadPlan effective water thickness values at off axis distances. After the modification CadPlan models the dose to within 2% of the measured values.

WIP-T-65

Fluence Error Reduction for static IMRT by Segment Weighting

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The translation of intensity maps to leaf sequences does not take head scatter and transmission into account on a first iteration since the knowledge of the segment geometry is needed to calculate these contributions to the fluence. To correct for these effects, some researchers subtract these errors from the original intensity map and perform the leaf sequencing on the modified map. This typically increases the number of segments by a factor of 2 to 4. For static IMRT this is undesirable, since the goal is to be able to verify, deliver and record each segment; treatments are much faster with fewer segments. In this work, the errors from these contributions are minimized by modifying the number of monitor units associated with each segment, thus maintaining the number of segments. Some leaf sequencing algorithms are more amenable to this type of correction and can reduce errors of about 10% to less than 3%. In one extreme case, an error of 80% was reduced to 3%. This work is funded by Siemens Medical Systems.

WIP-T-66

Monte Carlo Based Treatment Planning Using The PENELOPE Code System And CT Scan Data

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The PENELOPE Monte Carlo code system is applied to external electron beam treatment planning. A linac is modeled from the exit window to the phantom surface using the software package PENGEOM provided with the code system. Distal to the linac, a voxel matrix is used both to accommodate CT scan data and for dose scoring. Transport within the voxel matrix is done by moving a particle from one voxel to an adjacent voxel. The distance a particle moves is determined by the mean free path between successive events. We assume the patient consists of known materials. The mass density is allowed to vary (as determined by the CT number) and for adjacent voxels of the same material we scale the mean free path by the ratio of mass densities in the two voxels. This is computationally faster as it avoids sampling new cross-sections for cases where materials differ only by their mass density.

This approach requires a map of the mass density from a CT scan study. The stoichiometric method of CT scanner calibration is applied. Using a CT phantom and its associated material inserts, the CT scanner is characterized as a function of CT number, effective atomic number and electron density (electrons/gram). The resultant function is then used to convert a series of CT scans to mass density data for Monte Carlo simulation.

Initial results of the voxel transport show good agreement with measurement. Additional experiments using the Rando phantom are in progress and will be presented.

WIP-T-67

Portal Phosphor Plate Imaging

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Phosphor plate imaging provides an interesting alternative to conventional film-screen combinations for portal film imaging in Radiation Therapy Planning. The superior dynamic range of phosphor plate imaging of up to five orders of magnitude provides more tolerance for image capture and subsequent image processing, such as edge enhancement and histogram equalization techniques.

A series of comparative images were obtained at 6 meV to illustrate comparative imaging of phosphor plate and screen/film combinations. Phantoms of both anthropomorphic and geometric nature used to illustrate relative contrast and spatial resolution performance. It is concluded that phosphor plates offer an extremely attractive method of obtaining portal images.

WIP-T-68

Radiotherapy Treatment Optimization: Impact of Fractionation Schedules

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Much work is being undertaken on optimizing dose distributions, however for an optimal treatment plan fractionation should also be optimized. Recently, some clinical trials such as CHART and EORTC have introduced modified fractionation schedules.

It is useful to predict the effect on a tumor of these modified schedules in terms of a standard schedule. Two new proliferative standard effective dose (PSED) formulas which enable the clinician to visualize the efficacy of one fractionation regimen (given) in terms of another (standard) are presented. Both are based on the Linear Quadratic model and predict a dose in terms of a standard schedule. The first equation ($PSED_1$) calculates the effect of a schedule on a proliferative tumor in terms of the effect on a non proliferating tumor receiving a standard dose per fraction. The second ($PSED_2$) calculates the effect on a tumor growing at the same rate, treated with a standard dose per fraction:

These equations have been used to compare a series of clinical trials on a theoretical basis. Most calculations show at least equivalent tumor control for the modified schedule when compared to the control schedule, with the EORTC schedule showing the most improvement over the range of T_p values. The CHART schedule shows a dramatic improvement for short potential doubling times but a lack of effectiveness compared to a standard schedule of 30, 2 Gy fractions over 6 weeks for long potential doubling times.

WIP-T-69

Construction of the whole body frame

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3D whole body tophographic frame is designed and constructed on a single acrylic board. Two side panels are mounted on a frame board and each panel has a number of holes to support rods which are holding immobilizer on both sides. Between these panels, metal coordinate systems are encraved on a frame to measure z coordinate from head and neck to pelvis. Mev-green is used as an immobilizer and is supported by a number of rods on both side panels.

This system has advantages over the commercial type that gantry head can rotate freely in 3D conformal therapy and the frame system can be adjusted in length and width depending the patient's size. Localization is accomplished with z-ruler on side panels and x- and y- ruler above the frame and laser pointer. And this physical verification is used to compare with the software method based on digitized CT film which contains all three coordinates on it.

Better recycling materials are being searched for immobilizer, though mev-green is proven to be a proper substitute in that it is firm, light,easy to handle, and fast to harden. Research on the setup error has been performed on the focus of the movements of the internal organs, using the simulating fluoroscopy and possibly electronic control system for syschronizing respiration system in near future.

WIP-D-01

Neural Network Algorithm for the Quantification of Joint Margins for Rheumatoid Arthritis Assessment

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Rheumatoid arthritis (RA) can be assessed by measuring the narrowing of the joint spaces in the hands. These are ordinarily scored subjectively using radiographic images of the hand. Software which delineates and measures these joint spaces would add objectivity and speed to assessment of RA progression and potentially reduce the cost. We have developed a neural network based algorithm which segments the proximal and distal margins of the MCP, PIP and DIP joints. The results can be used to make a quantitative measure of joint space width and to assist segmentation algorithms.

Previously documented software was used to create cropped images in the vicinity of each joint. These were sectioned horizontally and pairs of candidate distal and proximal margin points were identified by a combination of several standard edge detection techniques. For each pair, 14 parameters, related to the grayscale and geometry, were input to a back-propagation, single hidden layer, neural network. Joint space margins, hand drawn by an expert radiologist, served as a gold standard for the training set.

The network was tested on a set of 15 hand radiographs and correctly identified joint space margin points at a rate of over 80%. Perfect success was not necessary since most failures could be identified by connectivity constraints with neighboring points.

We have developed software to quantify joint space geometry in radiographs of the hand which has the potential to provide an accurate measurement of joint space width for RA assessment free of the subjectivity of human scoring.

WIP-D-02

Registration Accuracy in High Resolution Dual-screen CR

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Dual-screen imaging technique can help improve image quality in computed radiography or be used to implement dual-energy subtraction imaging. With this technique, two storage phosphor screens are simultaneously exposed and then separately scanned to form a front and back image. These images can be synthesized to form dual-energy subtraction images or an image of improved signal-to-noise ratio and detective quantum efficiency in various imaging applications. However, the spatial resolution of the final synthesized image depends on the accuracy with which the front and back images are registered with each other. This study investigates the accuracy in registering dual-screen images acquired with a high-resolution laboratory CR imaging system under mammographic and chest imaging conditions. To this end, a matrix of 2mm diameter lead beads were imaged with various combinations of ST and HR screens and a pixel size of 86μm or 43μm for chest imaging and mammography respectively. Specifically, we evaluated and compared two different localization algorithms: the geometric center and the center-of-mass methods. Furthermore, we analysed the registration errors for various numbers and positions of fiducials used to compute the coefficients for rigid body transformation. The first part of our study indicated that both localization algorithms yielded subpixel accuracy. The second part of our study showed that the registration error decreased when a larger number of fiducials were used. When using four beads at corners, the error ranged from 0.2 to 0.6 pixel depending on the application and the screen combination used.

WIP-D-03

A Double Transmission Ionization Chamber for Dose and Dose-Area-Product Monitoring

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A double transmission ionization chamber has been constructed which allows a determination of patient entrance skin dose simultaneously with dose-area product (DAP). This double chamber consists of two measurement cells. One cell has a sensitive area which intercepts the entire x-ray beam and measures the total radiation incident on the patient or DAP; the second cell has a known sensitive area to measure radiation concentration or exposure. Two electrometers are used to read the charge collected from each cell independently. Just as standard DAP chambers, this chamber is mounted on the exit port of the x-ray collimator. The components of the chamber which are in the beam are uniformly attenuating for x-rays and are shown not to cast interfering shadows in the image of the patient. Entrance dose can be calculated using an estimate of source-to-skin distance from either prior measurement or the values obtained with a ranging device. The response characteristics of this chamber will be presented and evaluated as a function of exposure geometry, x-ray field area, and kVp. The goal of this research is to develop a monitoring system which can provide real-time feedback to the fluoroscopist so he/she can be kept apprised of the radiation risk to the patient. Use of this chamber will allow measurement of entrance skin dose to provide a warning when the thresholds for the deterministic effects of erythema and epilation may be exceeded during long interventional procedures as well as provide quantification of stochastic risk.

WIP-D-04

A New Radiochromic Film for Dosimetry During Interventional Procedures

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A new radiochromic film that is sensitive to diagnostic x-rays is currently under development. The film contains radiation sensitive components that have been enhanced to provide high sensitivity to diagnostic x-ray energies. The underlying technology is similar to that used in commercially available GAFCHROMIC® dosimetry media. The new film exhibits a response to diagnostic x-rays that is more than an order of magnitude higher than is achieved with the GAFCHROMIC® films. As with any radiochromic film, the new dosimetry film does not require chemical processing – an immediate, visible coloration occurs upon exposure to x-rays. When placed in the entrance x-ray beam during interventional procedures, the absorbance change of the new film permits the easy identification of those areas which have received the highest dose. With proper calibration, a quantitative measurement of this dose can be obtained by measuring the absorbance change in the film caused by the x-ray exposure. The absorbance measurement can be made using a densitometer, an optical scanner, or a spectrophotometer. Response data for several versions of the new film over the dose range of 100 – 900 cGy is presented, and a comparison is made with commercially available GAFCHROMIC® MD-55 radiochromic film. Response data is also presented for several different measurement wavelengths. International Specialty Products supported the research described in this abstract.

WIP-D-05

Correlation of Dose Area Product (DAP) and Patient Dose During Interventional Radiological Cardiac Procedures

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The aim of this study is to determine skin dose and effective dose received by a patient undergoing interventional radiological procedures and to correlate this with DAP (dose area product) measurements. A simulation of a coronary catheterisation, using a RANDO antropomorphic phantom, was made to determine iso-doses on the skin and to derive the optimal TLD position for patient skin dose measurements. Skin dose measurements using 8 TLD's attached at the level of the heart and simultaneous DAP measurements with a DAP-meter at the collimator exit of the x-ray unit were made. Time, tube voltage and tube current for all different projections used, were registered. The DAP was noted separately for cine and fluoroscopy. These skin dose measurements will be used in Monte Carlo simulations to determine the dose to various organs and effective dose. This is done using the Monte Carlo code MCNP and the human geometry generating code BodyBuilder to construct a mathematical phantom. A standard coronary catheterisation will be simulated, using the DAP contributions from different projections. The most irradiated regions are the right side of the back and the area under the right arm. We found a correlation between DAP and average TLD dose. DAP might thus be useful to determine surface dose, it is however not clear yet if DAP can be used as an indicator for local overexposure. The contribution to the skin dose from cine is significantly higher than from fluoroscopy in most coronary procedures. Left right catheterisation however makes an exception.

WIP-D-06

Monitoring 59Fe Uptake in Children with Juvenile Rheumatoid Arthritis (JRA)

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Abnormal Fe metabolism in JRA may include inappropriate deposition into affected joints. A position/energy-sensitive gamma counter, using four 100 cm-long detectors, has been developed to monitor ^{59}Fe activity at affected joints of JRA patients. Eight children (ages 5 - 15 yrs) were given 0.2 uCi of ^{59}Fe intravenously, then measured two hours later. Measurements were also obtained at 7, 14, 28, and 56 days. Two detectors positioned alongside the supine child measured affected joints (elbows, wrists, and/or knees), while two detectors below the bed measured the whole body. Data from the lower detectors were in agreement with that from a second whole body counter; both systems showed >90% ^{59}Fe retention. For the last 2 children's scans a more comfortable arrangement was used for measuring affected joint activity. Subjects sat in a chair with a detector placed alongside each arm, while a third detector was positioned against the subject's knees. For all 8 subjects, the activities per 10 cm segment at the affected joints were compared to the whole body data. 6 of 8 subjects showed increased uptake of ^{59}Fe in affected joints (~165%) over the first 30 ($\pm$ 5) days when compared to initial values. We conclude that a position-sensitive counter can provide a noninvasive method for monitoring regional uptake of ^{59}Fe in JRA children using very low doses (<0.03 mSv), and can be used to measure other radioisotopes as well.

WIP-D-07

A spectral Approach for the Measurement of the Absorption Characteristics of Scintillators for Digital Mammography

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Vapor deposited cesium iodide scintillators are of renewed interest for use with amorphous silicon or charge-couple device imagers in digital mammography and other radiographic applications. The DQE of these systems is critically dependent on the absorption and light output of the scintillator. The absorption of CsI(Tl) was computed for various thicknesses from experimentally derived mammographic x-ray spectra at 28 kVp using a CdZnTe spectrometer. The absorption of CsI(Tl) was computed by combining the literature value of linear attenuation coefficient at each energy in the x-ray spectrum with its relative abundance. The absorption efficiency of 100 m layer is 72 % and 70 % for the unattenuated beam and the hardened beam past a 4.5 cm breast equivalent phantom respectively. The corresponding values for 150 mm layer were 84 % and 82 % and for a 200 micron layer were 91 % and 89 %. The use of the weighted spectral approach, based on measured spectra, provides a more accurate means of assessing the absorption characteristics of phosphors than using the non-weighted mean energy. These results suggest that a 100 micron layer of CsI(Tl) is adequate for x-ray absorption which is comparable to other mammographic screen technology. A greater thickness, up to 200 microns would be beneficial but it would affect the spatial resolution. The lack of high absorption and high conversion x-ray scintillators presents a significant challenge in meeting the needs of digital mammography and high resolution radiography.

WIP-D-08

Sensitometric Characteristics of Low Noise CCDs for Mammographic Imaging

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Single or tiled CCD arrays are used successfully for small-format and full-field digital mammography. Tapered fiberoptics or lenses used for optical coupling between scintillator CCD have a very low optical efficiency. Therefore, understanding CCD sensitivity at low light levels is a critical concern. A 1K x 1K pixels cooled low noise CCD camera (0.024 micron pixels) was used with a non-tapering fiberoptic element (Photometrics Ltd.). Sensitometric measurements were performed with an Am-241 (59.54 keV) source using various scintillators in contact with the fiberoptic plate. The number of gamma-rays incident on the scintillator was determined by using a CdZnTe spectrometer. The source was placed on the scintillator-fiberoptic-CCD assembly maintaining the same distance and aperture as in the CdZnTe measurement. Images were acquired for different integration times and the dark current was subtracted from each image. Based on measured intensity per pixel and the knowledge of the number of incident gamma-ray events, the sensitometric response of the CCD was measured as a function of the detected gamma rays by the scintillator. A sensitivity of a few hundred electrons on average per detected gamma ray was observed, provided we could clear the bias charge and dark current of the CCD. However, a minimum signal of approximately 3,000 electrons per pixel is required to view an imaged object due to the bias charge and the dark current. The results provide insight on the capabilities and limitations of high sensitivity CCDs for mammographic and radiographic applications.

WIP-D-09

Stripping and Segmenting the Cerebellum

M. Zaini *, J. Anderson, D. Rottenberg, Veterans Affairs Medical Center, Minneapolis, MN

We are studying the metabolic anatomy of hereditary ataxia. In order to extract and characterize disease-related covariance patterns that provide new insights into the pathogenesis of cerebellar dysfunction, an ultra-high-resolution T1-weighted MRI will be used as a template for creating an anatomical atlas of the cerebellum. Segmenting the cerebellum into gray matter, white matter, and CSF is more feasible if the cerebellum is isolated from the rest of the brain. Since the original Talairach coordinate system does not explicitly include it, we have devised a new coordinate system for the cerebellum. This coordinate system is defined by two orthogonal planes: a plane passing through the obex-posterior-commisure line and the midsagital plane.

Isolation of the cerebellar volume from surrounding cerebrum, brainstem, and CSF, accomplished using semi-automated techniques, yields a 3D cerebellar mask. The deformation field obtained from warping the template brain volume to normal or abnormal brain volumes is used to create cerebellar masks. Four segmentation algorithms based on different underlying principles will be evaluated by segmenting the stripped cerebella of six subjects after correcting for MR field inhomogeneity.

WIP-D-10

Design of SPECT System for Ultra High Resolution Imaging of Small Objects.

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A study is conducted to optimize the design of a multi-pinhole collimator for high spatial resolution SPECT imaging of small objects (wrist, thyroid, breast or small animals). High resolution is achieved by using pinhole collimation; adequate sensitivity is obtained by using multiple pinholes and acquiring projections over 90° to 360° degrees around the object. Monte Carlo simulation studies and analytical methods are applied to determine the number of holes, hole position, hole aperture size, conical field of view, and focal length of the collimator needed to optimize spatial resolution and sensitivity for full and limited angular sampling imaging geometries. Special emphasis is placed on pinhole apertures 0.5-2 mm in diameter to achieve resolutions of 0.8-5 mm at the distances of 4-15 cm. An image reconstruction algorithm for rotating single pinhole SPECT based on a modified cone-beam algorithm that is a generalization of the 2D fan-beam filtered backprojection algorithm is being modified to accommodate simultaneous imaging from multiple pinholes with and without limited angular sampling. Simulated phantom studies include: 1) a 3 cm dia. sphere filled with uniform distribution of activity, 2) five Tc-99m point sources placed 1 cm apart in plastic spheres 3, 5 and 10 cm in dia., and 3) several smaller spheres (0.5-3 cm dia) containing Tc-99m placed in 3, 5, and 10 cm dia. spheres. Resolution properties superior to those achieved with conventional SPECT imaging technologies can be achieved with multi-pinhole SPECT.

WIP-D-11

Relation of Drug Side Effects in Epileptic Children With Valproate Treatment

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Valproic acid (VPA) now is regarded as an important - wide spred use both as sole medication and as a component of multiple drug regimes. It has been suggested that side effects of treatment (liver damage, bleeding tendency, etc.) With VPA maybe due to altration of some trace metal status such as Cu, Zn, and Se.

In our investigation the concentration of Cu, Zn and se in the serum of 25 children treated by VPA (group 1) were measured and compared against these elements in the serum of 25 healthy children (group 4). The same comparison were made between the two groups of children, first treated by VPA together with other antiepileptic drugs (AEDs), (group 2), and the second treated by AEDs except VPA (group 3). This comparison were performed in order to find out the probable effects of epilepsy disease on the concentration of those elements.

We measured Se. by PIXE technique and Cu and Zn by PIXE and AAS. The mean values (Mg/d. lit.) of measured concentration of these elements are compared. According to this investigation consumption of VPA decreases Cu levels but dose not alter the concentration of Zn and Se significantly. Also - duration of VPA therapy has no significant relation to - cu levels.

WIP-D-12

Updating the Agfa Component of the AAPM Task Group #10 Draft Report on Computed Radiography Acceptance Testing and Quality Control

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Updating the Agfa Component of the AAPM Task Group #10 Draft Report on Computed Radiography Acceptance Testing and Quality Control. [1]Charles E. Willis, Ph.D. and [2]John J. Lobick. [1]Department of Radiology, Baylor College of Medicine, Houston, Texas; and [2]Agfa Division, Bayer Corporation, Des Plaines, Illinois.

AAPM Task Group #10 was convened in December 1991 to compile and provide a single source of information for clinical users of Computed Radiography (CR), who were faced with conducting acceptance tests and quality control of this new imaging technology. With active participation from all three CR manufacturers, the Task Group produced a draft of their report that is frequently used as an informal reference. Over the years, the Agfa CR product line has evolved and the experience base within the US has expanded considerably, requiring a significant update of the report content. Our update reflects this increase in clinical practice and incorporates feedback from clinical users. Tests are described in a manner that should have more practical utility for the physicist in the field. The revision includes reformatting and clarification of features including image processing and dose monitoring. In conjunction with the revision, we are including performance data from clinical sites. This presentation will detail changes in the Agfa CR product line, specifics of recommended tests, and the relationship between Agfa tests and tests recommended in the body of the Task Group report.

WIP-D-13

Lymphocytes as Biological Dosimeters

A. Ralston *, P. Reece, G. Stevens, S. Prosser, Royal Prince Alfred Hospital, Sydney, Australia

Introduction. In the investigation of radiation accidents the physical dose received by accident victims may not be measurable, in which case the dose should be estimated by biological methods, such as analysis of chromosomal aberrations in the peripheral blood lymphocytes. Currently there is no facility to do this in Australia. This aim of this project is to produce a set of blood samples that have been irradiated to accurately known doses in order to establish baselines for an Australian biological dose centre and to compare with results from other institutions.

Methods and materials. A Pantak DXT 300 X-ray unit is used for the irradiations (250 kV, HVL 1.2 mm Cu). Since the blood samples must be maintained at 37^{O}C complex irradiation jigs have been used previously such as water baths with circulating warm water. To simplify the irradiation method the temperature constancy and dose homogeneity is being investigated for lightweight insulating materials and solid phantoms. LiF TLD chips are being used to map out dose homogeneity in the blood vials. For unilateral irradiation a solid perspex phantom achieves superior dose uniformity across the vial than a polystyrene foam phantom. For acceptable dose homogeneity (within 2%) bilateral irradiation is required for either phantom. Both phantoms have good thermal insulating characteristics. After irradiation the cells will be cultured,

mounted and stained in preparation for microscopic analysis of the chromosomal aberrations.

WIP-D-14

The Establishment of Risk Factors for Skin Injury from Fluoroscopic Imaging

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Some interventional and cardiac procedures require long exposure times. Although exposure time is an indication of the potential for skin burns, it is not a good indication. The entrance exposure rate to a patient can vary by up to two orders of magnitude as a result of the thickness of tissue through which the x-ray beam travels to reach the image intensifier. This is exacerbated in lateral views in which the skin surface is also closer to the x-ray tube.

This presentation establishes a rationale to allow a risk factor for an individual patient to be determined from a preliminary knowledge of their height and weight. This risk factor, combined with the exposure time gives a much better indication of the likelihood of a skin burn from a given fluoroscopic procedure than exposure time alone. It is not a complete indication as the beam may not irradiate the same area for the entire duration of the procedure. Furthermore, cine and digital run times are often not documented. An estimate of the additional dose from cine and digital procedures will be given.

Data will also be presented in the relationship between height, weight and trunk size. This effective trunk size on skin exposure rate will be used to give a relative risk factor for a given patient for a given exposure time.

WIP-D-15

Computational Model For Studying Performance of 1.25-D and 1.5-D Ultrasound Transducer Arrays

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Current linear and phased array transducers suffer from poor slice thickness because electronic focusing affects beam widths only in planes parallel to the ultrasound image plane. 1.25-Dimensional (1.25-D) and 1.5-D transducer arrays enable electronic control of elevational focus and should lead to substantial improvements in spatial
resolution. However, thus far their use has been limited because of cost and complexity.

We are developing a computational model for studying how array parameters affect B-mode imaging performance. Our frequency-domain model computes fields for pulsed transducers and produces simulated images of media containing randomly positioned scatterers. The algorithm readily allows incorporation of 1.5-D array designs, with only a modest computational overload. As expected, simulations readily demonstrate that 1.25-D and 1.5-D arrays provide much better slice thickness control than standard 1-D arrays. The effects of different designs, such as the number and size of rows in the elevational direction (and consequently the required channel density) are being investigated by comparing performance with that of a "perfect" linear array, which dynamically focuses at all depths in the elevational direction. Images of digital "lesion" phantoms containing simulated focal masses of various diameters and backscatter contrasts are obtained, and detectability and signal to noise ratios for practical arrays are compared to those generated by this hypothetical "perfect" array. It is anticipated that computational models will facilitate more rapid optimization of these arrays for specific imaging applications.

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