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Analysis of IMRT calculations and measurements using the TG119 document at the Radiotherapy Center of Suriname (RTCS)

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The purpose of this work was to revise how well XiO treatment planning system (TPS 4.80 patch 3), Intensity Modulated Radiation Treatment (IMRT) calculations are delivered by an Elekta Synergy Platform-MLCi2 machine using Task Group 119 (TG119) benchmarked data of the American Association of Physicists in Medicine (AAPM) in order to implement future IMRT treatments at the Radiotherapy Center of Suriname. The approach delivery was steep and shoot and measurements were performed for the four geometries (except C Shape harder) mentioned on the guide document TG119. The photon energy 10MV was also considered. Using the XiO TPS, fixed-beam IMRT treatment plans were constructed based on the structure sets copied to a parallelepipedic phantom, which consist of solid water slabs. The plans were delivered to the phantom using the Elekta machine mentioned above and the resulting dose distributions were measured in the coronal plane using EBT3 Gafchromic films. Measured planar dose distributions were analyzed using gamma index with criteria of 3 %/3 mm. Also, point measurements were taken, five times each, using a 0.125 cm³ scanning chamber situated in the same positions recommended. The confidence limit was obtained for both cases film and point measurements for ulterior comparison with the benchmark provided. The results showed that clinical implementation of IMRT only can be justified for simple IMRT calculations, like those developed in prostate’s anatomy, because an increase on complexity of IMRT plans (H&N) could produce important discrepancies between radiation doses calculated and those delivered by the linac.

Commissioning of Radiotherapy Treatment Planning Systems: Optimization of the Dosimetric Test of the IAEA TECDOC-1583 guidelines

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Background: Independent external audits play an important role in quality assurance in radiation oncology, for this reason the International Atomic Energy Agency (IAEA), in its technical document IAEA-TECDOC-1583, recommends a procedure to establish quality assurance of Radiotherapy Planning System (RTPS) using the IMRT Thorax Phantom (CIRS - 002LFC). The procedure is based on an anatomical test to verify the digitization of contours and the reproducibility of the RTPS and a dosimetric test to check the range of clinical treatment, which consists of eight cases able to simulate clinical situations. This research was focused in optimizing the dosimetric test, keeping tolerance limits and configuration proposed by IAEA.

Methods: This study consisted in correcting the previous mentioned procedure giving the fact that measurements were not done in water cavities, if not in lung, muscle or bone equivalent materials. It was applied for six combination of planning algorithms and high-energy photon beams. The CIRS was scanned with a computed tomography (CT) and treatment plans for eight different test cases were planned on local RTPS. The phantom was irradiated following the treatment plans for these test cases and doses in eight specific points were measured with a semiflex ionization chamber. Results: Differences between the measured and calculated doses were reported by both methodologies. Slightly differences between measurements with and without the correction were appreciably for those tested in bone and lung equivalent materials, being even less in muscle.

Conclusions: This work showed a methodology to optimize the procedure described by the IAEA, bringing the measured dose closer to the planned dose, being these results extensible to advanced techniques quality assurance, such as VIMAT and SRS. It also helps us to better understand a more real way to employ the TEC-DOC 1583.
Commissioning DCAT/VMAT with 6 MV FFF for SRT

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Currently at our centre, the stereotactic program uses 6 MV cFF and forward planning techniques: cones for SRS, conformal MLC for SRT. Patients are immobilized with either the non-invasive Aktina stereotactic frame or a thermoplastic mask. Treatment localization is performed with CBCT. We are implementing DCAT and VMAT for SRT with 6 MV FFF to reduce treatment time, treat larger non-spherical lesions, and treat multiple lesions simultaneously. We investigated using different beam geometries, 1 arc, 3 arcs and 5 arcs, for both one and two lesions. Planning was completed in Monaco 5.11 and delivery with Elekta Agility MLC. Fluence measurements were taken with MapCheck and compared to TPS. Absolute dose measurements were acquired with an ion chamber at 4 off axis distances in the Steev phantom and compared to TPS. We selected 3 non-coplanar arcs as the preferred beam geometry. DCAT and VMAT both produced clinically acceptable plans that met our institutional guidelines. DCAT plans had fewer total MU and had higher DTA/dose passing rates and had fewer delivery interrupts. VMAT plans could achieve better OAR sparing when critical structures are near the lesion. Optimization time was similar, as both methods used a 1 mm dose grid. In conclusion, acceptable SRT plans can be produced with 3 non-coplanar arcs and the FFF beam using both DCAT and VMAT techniques.

Commissioning of two Sensus SRT-100 50 - 100 kV X-ray unit for skin cancer treatment

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This study provides dosimetric data from the commissioning of two Sensus SRT-100 50–100 kV X-ray units. Data collected during the commissioning process included: a) HVL, b) output (dose rate), c) applicator cone factors, and d) profiles. Percentages depth dose were not measured due to lack of resources. Farmer-type chambers (iba-FC65-G), and a thin-window parallel plate ion chamber (PTW-N23342) were used for HVL measurements. Dose rate measurements were made with two thin-window parallel plate ion chamber (PTW-N23342). Dose profiles were measured with EBT3 GafChromic film. The average HVL values for 50, 70, and 100 kV of the two treatment units were found to be 0.52, 1.13, and 2.03 mm Al, respectively when plane parallel chamber were used and 0.55, 1.16 and 1.98 mm Al for farmer types. The HVL’s were 2.4%–5% lower when measured with the Farmer chamber, as compared to measurements with the parallel plate chamber, for energies of 50 and 70 kV, that differs to Sheu et all. Dose rates were measured for 50, 70 and 100kV at 15 and 25 cm SSD. The dose rate variation for two units was below 2%. Applicator factors deviation were also below 2 %. The dose profiles for the 5 cm applicator were nonuniform, especially in the cathode–anode direction. The data obtained shows good stability for this type of machine and the necessity of redundant verification.

Comparison between different Monte Carlo codes in the modeling of an Elekta Precisa linac head

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Several Monte Carlo (MC) codes are available for performing radiotherapy dose calculations, with acceptable accuracy. The objective of this work is to analyze the differences in the calculations obtained by different MC codes and their impact on the absorbed dose evaluations. In order to evaluate the possible systematic differences, a comparison was made between different electromagnetic physics packages of the Geant4 application for tomographic emission (GATE) 8 versus Monte Carlo N-Particle eXtended (MCNPX) 2.6 and Gamma electron shower (EGSnrc). To do this, we used a similar geometry for the three codes based on the linear accelerator (linac) head of an Elekta Precise for 6 MV photon
beams used in standard therapies. Field sizes of 3 x 3 cm$^2$, 5 x 5 cm$^2$, 10 x 10 cm$^2$, 15 x 15 cm$^2$ and 20 x 20 cm$^2$ were considered. The reference values of the percentage depth dose (PDD) and the beam profiles were obtained in the water phantom and in the ionization chamber.

**Poster Session - MP / 100**

**Comparison of relative renal function and images through studies with radiopharmaceutical $^{99m}$Tc-MAG3 y $^{99m}$Tc-DMSA**

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Relative renal function and differences in the images of kidneys through renal gammagraphy with radiopharmaceutical $^{99m}$Tc-MAG3 and $^{99m}$Tc-DMSA was compared. For the study a sample of 50 patients was analyzed, in which 75% were children. Images were acquired with a double-headed AnyScan SC gamma camera of MEDISO Company. The renal gammaphraphy with $^{99m}$Tc-MAG3 was processed as a DMSA study, using the DMSA protocol, taking the sum of first images. Comparison in RRF of left kidney (used as reference) between both studies show a correlation coefficient of 0.996 and a slope value of 1.02±0.01. The images were analyzed by nuclear physicians of ten or more years of experience leading to similar conclusion that sum first images of $^{99m}$Tc-MAG3 renography can be informed as a DMSA study, only when in the diagnosis the patient doesn’t present ectopic kidneys. This results show that relative renal function obtained in a DMSA study can be obtained through a renography with $^{99m}$Tc-MAG3 taking the first images previous to pelvis drainage. In this we can avoid overexposed patients submitted to both studies, avoiding loss of time and guarantee savings of material.

**Poster Session - MP / 214**

**Computational approach of the interaction of gamma radiation coming from neutron capture on biomolecules via GEANT4**

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Since its discovery in 1935 by J. Chadwick, neutrons have been used in many fields, from power production to medical applications. In particular, G. L. Locher in 1936 came out with the idea of using neutron capture for cancer treatments. Currently the Neutron Capture Therapy (NCT) stands for a binary treatment method that combines a cancer specific Boron ($^{10}$B) or Gadolinium ($^{157}$Gd) labeled drug and a neutron beam of a low energy sufficient for neutron capture to take place within the treated tissues. The nuclear reaction that takes places into the cell releases gamma radiation of 0.478 MeV for $^{10}$B and 2.2 MeV for $^{157}$Gd. In this work we present a GEANT4 study of the interaction of this gamma radiation on bacterial DNA of “staphylococcus aureos”.

**Poster Session - MP / 217**

**Computational approach to the interaction of Li coming from neutron capture on biological cells via GEANT4**

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After the discovery of neutrons, G. L. Locher proposed the idea of using neutron capture for cancer treatment - Neutron Capture Therapy (NCT). This treatment method combines either a Boron ($^{10}$B) or Gadolinium ($^{157}$Gd) labeled drug and an epithermal neutron beam suitable for neutron capture to take place within the treated tissues. With a branching ratio of approximately 94%, the $^{10}$B nuclear reaction taking place inside the cell releases gamma rays of 0.478 MeV, alpha particles of 1.47 MeV and $^7$Li ions of 0.64 MeV. Using GEANT4, we present in this work a study of the effects of these final-state particles on biological cells.
Computational approach to the sterilization of the human amniotic membrane using ionizing radiation via GEANT4

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In the last decades the use of the Human Amniotic Membrane (HAM) in regenerative and curative medicine has been significantly increased. The sterilization processes of the HAM are crucial for its clinical use. In order to preserve the main biophysical and biochemical properties of HAM, improvements are required in the sterilization procedures, in which some of the valuable HAM's properties are lost. Currently most of HAM's clinical sterilization protocols are based on biochemical processes with antibiotics and glycerol. Recently sterilization studies with ionizing radiation reported up to 25000 Gy radiation sterilization dose to obtain the so-called sterility assurance level. We are considering a simple and valuable approach to the preparation of HAM by antibiotic and glycerol combined with radiation sterilization. In this work we present a GEANT4 study of the interaction of bacterial DNA of "staphylococcus aureos" with two different ionizing radiations.

Design shielding assessment for a nuclear medicine service

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It is recognised worldwide that the security of radioactive materials is very important and that the design of facilities where these sources are used and stored must cater for the implementation of good security measures, including the shielding of some treatment and diagnostic rooms. The radiation protection assessment of a nuclear medicine facility consists of the evaluation of the annual effective dose both to workers occupationally exposed and to members of the public. This assessment take into account the radionuclides involved, the facility features, the working procedures, the expected number of patients per year, the administered activity, the distribution of rooms, the thickness and physical materials of walls, floors and ceilings and so on. The assessment results were compared to the design requirements established by the Cuban regulatory body in order to determine whether or not, the nuclear medicine facility complies with those requirements, both for workers and for members of the public. The evaluation presented is useful for facility designer and for member of regulatory body.

Design, construction and evaluation of a cylindrical phantom for the quality assurance in Computed Tomography

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Was designed and produced a cylindrical phantom in PMMA material for evaluate the image quality parameters: spatial resolution, high and low contrast, magnification, uniformity and reproducibility of Hounsfield numbers for Computed Tomography (CT) through the formation of images in the acquisition of tomographic images. The phantom was designed and built under the recommendations of international
quality control protocols in CT. Initially its geometry was simulated in GEANT4 and then constructed in axial sections by means laser cutting technology. Subsequently, physical properties such as density, shape and size of each component were established. Internal holes were inserted into the acrylic discs (modules) and filled with selected materials to evaluate the contrast of the image. Metal pieces and wires were incorporated to evaluate the thickness of the tomographic sections. Also within the same module were established objects to determine the spatial resolution of the tomographic system. The Phantom was evaluated in three hospital centers in Tunja city and tomographic axial images were analyzed using a specialized software where were determined Hounsfield numbers of each structure and its tolerance range. Finally, results were intercompared and validated with a phantom Catpham 500 certified, obtaining differences smaller than 5% in the estimation of the densities of materials of reference.

Poster Session - MP / 10
Determination of transmission factors for an $^{85}$Kr beta radiation beam using an extrapolation chamber

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The $^{85}$Kr isotope is a beta-ray emitter (gas) with a half-life of 10.76 years. It is produced in the fission of Uranium and Plutonium. The sources of this isotope are the nuclear tests, the nuclear reactors and the reprocessing of nuclear fuel. In the gas release events around reactors, the $^{85}$Kr may represent a major hazard. In beta emitters, in order to evaluate the absorbed dose rate at different tissue depths, it is necessary to determine the transmission factors. In this work, the preliminary results of the determination of transmission factors of the $^{85}$Kr source of a BSS2 beta secondary standard are presented. For this purpose, an extrapolation chamber was used. The results obtained are considered acceptable, and they are within the uncertainties, in comparison with the values provided by the source calibration certificate (PTB, Germany). The maximum difference between the results determined in this work and those from the calibration certificate was 3.8%.

Poster Session - MP / 242
Development of F(ab')$_2$ fragment Monoclonal Antibody h14F7 for radiodiagnostics of tumor positives to N-glicolil-GM3 ganglioside

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14F7 is a murine monoclonal antibody that recognizes the ganglioside N-Glycolil GM3 and induces death in tumor cells that overexpress this ligand. Antibody fragments exhibit improved pharmacokinetic properties as compared to whole antibodies. The study was based on two assumptions: first, the h14F7-F(ab')$_2$ does not lose its biological activity; second, labeled with $^{99m}$Tc, have a more favorable pharmacokinetic behavior for its use in radiodiagnosis. After pepsin digestion, 10 mg/mL of fragment was obtained with 40 % of recovery. Schwarz method was used for radiolabeling both h14F7 mAb and its F(ab')$_2$ fragment. The quality control was performed by means of paper chromatography, where yields of 99.04 ± 0.27 and 97.21 ± 0.21 %, respectively, were obtained. In vitro studies verified the high stability of $^{99m}$Tc-F(ab')$_2$ and $^{99m}$Tc-h14F7. Biodistribution of radioimmunoconjugates was evaluated in healthy BALB/c mice and in a tumor model with the administration of equimolar amounts, reflecting lower uptake in non-target organs for $^{99m}$Tc-F(ab')$_2$, and scintigraphic images presented a target to non-target ratio due to a faster clearance as demonstrated in pharmacokinetic analysis. $^{99m}$Tc-F(ab')$_2$ have good possibilities of being used in radioimmunodiagnosis, with diminished risk of toxic and radiotoxic effects due to the permanence or accumulation of the radiolabeled ligand.
**Poster Session - MP / 188**

Development through in silico experimentation of equations that predict the range of protons and carbon ions in brain and ocular tumors

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In this work the study of the Deposited Dose Distributions in depth by Protons and Carbon Ions in different Phantoms, was made with Monte Carlo Method. Initially, a simulation of the interaction of the charged particles (Protons and Carbon Ions) with water was constructed with the Geant4 tool (Fig.1.). The Bragg peaks and Deposited Dose Maps at multiple energies within the therapeutic range were calculated to validation purposes (Fig.2.). Subsequently, the transport of Protons and Heavy Ions on Equivalent Human Tissue and high density materials as bone was studied. Also, the interaction of Protons and Carbon Ions with a human-headed phantom, which includes the detailed geometry of the eyes, was simulated (Fig.3.). The Bragg Peaks and Deposited Dose Maps were calculated to obtain the equations that predict the range of Protons and Carbon Ions in brain and ocular tumors.

**Poster Session - MP / 293**

Dose deposition in small lung lesions: Modifying the PTV for a more robust optimization

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In lung cancer, SBRT is used to deliver high doses to a small dense GTV moving into a low-density tissue (margin generating the PTV). If IMRT or VMAT are used to treat such inhomogeneous PTV, a homogeneous dose distribution is achieved generating high photon fluence inside a 3D shell (PTV-GTV). Paradoxically the dose distribution is apparently uniform, but the GTV, which moves into the PTV, will receive a dose that depends on its position. This work studies this phenomenon. Monaco v5.11 (Elekta, SWE) with MC algorithm was used to simulate a SBRT treatment. In a first part, the photon fluence was optimized for the original PTV electron density (EDo) and then used to recalculate the dose on a modified PTV electron density (EDf) in which the mean value of the GTV electron density was forced as the relative electron density of the PTV. In a second part the photon fluence was optimized for PTV EDf and then used for the dose calculation on PTV EDo. In part one, dose increments of 1.6% for D98%, 2.5% for Dmean and 5% for D2% were obtained for PTV-GTV, dose profiles calculated on EDo and EDf, differ up to 6.6% on longitudinal axis along the plan isocenter. A maximum dose difference of 9% of the prescribed dose was obtained between the 3D dose distributions. This means, when the GTV reaches a position inside the PTV, where the photon fluence is optimized for low electron densities, it will receive higher doses than what estimated on the original EDo map. In the second part a reduction of -1.5% for D98%, Dmean and D2% were achieved for PTV-GTV and the maximum difference between dose profiles was -3% for longitudinal axis. The maximum difference between the 3D dose distributions was 6% of the prescribed dose. The GTV is thus irradiated in a more homogeneous way in part two in which the fluence is optimized for its mean electron density everywhere in the PTV. We propose that, in lung small lesions, the PTV must be modified in terms of electron density considering the GTV mobility.

**Poster Session - MP / 94**

Educational experiences in Medical Physics

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Medical physics (MP) is a well established discipline since a few decades, both in the clinical practice and in education. However the urgency and need for human resources, in particular in countries where
science and physics in no well developed, points for innovative educational initiatives. In this talk we review the situation in undeveloped countries, with emphasis in Latin America. In particular we address the experience in Uruguay, where, in contrary to the common trend a bachelor MP degree of 4 years is the starting point for education in the subject. The status of undergraduate and graduate studies will be presented, as well as the benefits and disadvantages of this approach will be discussed.

Poster Session - MP / 205
Evaluating the performance of PET/CT Gemini TF64 for dynamic 4D PET/CT imaging for radiotherapy treatment planning using the CIRS 008A thorax phantom

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The availability of tools for visualize, control, and track patient specific respiratory motion could improve the accuracy in radiation therapy for thorax and abdomen tumor lesion. If smaller treatment fields are used, there is the possibility of target may move out of the treatment field resulting in an under dose to the target and surrounding normal will be exposed. The goal of this work is the evaluation of the tools for dynamic 4D imaging of the PET/CT Phillips Gemini TF64 system in-stalled at INOR for radiotherapy treatment planning of tumors located in thoracic and abdominal cavities which could be influenced by respiratory motion. The performance of PET/CT Philips Gemini TF64 system was previously verified by following the recommendations given in the documents IAEA 1393 and 1557. The CIRS 008A Dynamic Thorax Phantom was used during the tests for simulation of three-dimensional target motion controlled by the CIRS Motion Control Software Model 008PL. The influence of CT acquisition parameters and reconstruction for three simulated respiratory cycles (20bpm/15mm, 10bpm/15mm and 15bpm/25mm) on the gated image quality, geometric accuracy of detection and delineation of moving target with different sizes (10, 20 and 30 mm) were studied. The results using 4D CT and non-gated CT were compared with those obtained using CT acquired without target motion. Three refillable spherical inserts with diameters similar to those used for CT acquisitions were built and adapted to CIRS thorax phantom in order to evaluate the dynamic 4D PET and 4D CT performance of PET/CT Gemini TF 64 system. These in-house made inserts were filled with a Ga-68 radioactive solution (18.5MBq/cc) containing radiologic contrast media. PET/CT acquisition without target motion were used as reference. The effect on SUV measurement for moving target of three types of attenuation correction images used for reconstructions: (a) the free-breathing CT for all PET phases, (b) the average CT for all PET phases and (c) 4D CT for phase-matched attenuation correction were compared. The results obtained matched with those reported in similar experiences using phantoms. Larger targets provide higher registration accuracy than small targets. Different respiratory cycles affect the registration accuracy. Increasing the respiratory amplitude will decrease the accuracy. Nevertheless this is the first experience in our country performing these studies the experiments and their results are the starting point for discussion to establish methodologies for commissioning other imaging systems with 4D imaging tools in Cuba, QC/QA program and acceptance limits.

Poster Session - MP / 265
Evaluation of the fluoro alkil losartan-derivative as 18F-labeled radiopharmaceutical candidates for cancer diagnosis: theoretical study

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There is sufficient information in vitro and in vivo that indicates that AT1 receptor (part of the blood pressure regulated system Renin-Angiotensin) is overexpressed in malignant tumor. The losartan is one of the most studied antagonist of this receptor, for that reason, this study evaluated the fluoro-alkyl losartan-derivatives (18FAL) as potential candidates of 18F-labeled radiopharmaceuticals for cancer diagnosis. Each derivative is obtained by a SN2 reaction. All calculation is performed in vacuum as first approximation. The stability of these compounds is studied using the Density Functional Theory with the
Molecular-Docking (MD) is used to estimate the association with this receptor. The functional M06-2X is the best that describes the featuring of these systems. The vibrational frequencies of the members of family 18FAL structures and the bond dissociation energy (BDE) are also calculated. The most stable derivative is 18FML(n=1), followed by 18FPL(n=3) and 18FEL(n=2) (n=CH₂). Atoms in molecules topological study is done to characterize the bones and weak intramolecular interactions. All the intramolecular interactions are of the Van der Waals type, the fluoro-alkyl chain provides additional stability to the molecule, in addition to generating a phenomenon of folding in this derivatives. MD explains the probability of existence of two conformers, one of them orients the phenyl and tetrazol rings in the same way as the natural ligand within the crystallographic structure of AT1 receptor. The amino acids that most contributes to the stability of the ligand-receptor complex are: Arg-167, Ile-288, Trp-84. 18FML is proposed as the best candidate.


Exposed Occupationally Worker Dosimetry at Interventionism Techniques

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Very soon is going to work in Cardiological Center of Villa Clara, Cuba, a new brand of X ray De-vice, (that is X Ray in C Arm), that includes electrophysiology functions, in which the irradiation time might be longer in comparison with Hemodynamic Machines and interventionist cardiology, where take place several procedures of less duration such as angiographies and angioplasties. It is shown the experience results of dose to the doctors of interventionist cardiology, using TLD and RPL detectors, in different parts of the body that demand the radiologic protection. Measurements are mainly made at crystalline, limbs and the whole body. It is taken into account the fact that at the time to perform recordings, the dose to apply must be higher that is the irradiation of gamma rays is higher at this time. It was used in addition the dosimeter RDS30 and the DCM 3000 in measurements of different regimes of professional work performed with patients. The recorded dose to the interventionist doctors show the great need to keep a permanent and effective surveillance, they are controlled regarding with the kind of procedure, pathologic indication, fluoroscopy time and machine, generating estimation of the patient dose. The doses to the limb of the cardiologic specialist were measured using TLD.

The dose at the crystalline are recorded placing TLD, a Little bigger with its three cells, that it is pro-posed to improve through an IAEA project. It is also placed a second witness out of the protection media, that is the glasses with lead protection 5 mm equivalent, besides it is informed the dose of thyroids and limbs of the cardiology specialist. The other report of dose is at the heart level of the Doctor under the protection and without protection. In each procedure it is reported the accumulative dose of the performed intervention. It is also reported the average time in minutes of each procedure. Both C Arm devices record a useful information level to the redundant estimates of the likely dose to be received by the doctors and the surveyed patients.

It is confirmed the need of the irreplaceable systematic practice in the preparation in items of radiological protection for all the personal that works at cardiovascular interventionism.

Keywords: TL Dosimeter, Interventionism, Equivalent Dose, Specialist Doctors, Radiological Protection.
Feasibility of using a thyroid probe for $^{131}$I intake surveillance of nuclear medicine workers

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This research, propose a monitoring procedure of $^{131}$I intake of nuclear medicine workers using the thyroid probe of the Nuclear Medicine Department. The Thyroid Counter used is a gamma probe, equipped with a lead shielded NaI(Tl) scintillation detector of 30x30, also was studied the gamma camera Phillips Forte with NaI(Tl) 3/8” pinhole collimator-5mm. The efficiency calibration was performed with a thyroid phantom, simulating the adult thyroid anatomical shape and volume, filled with radioactive solution of known activity of $^{131}$I (uncertain activities of 2.24%). The intake and the effective dose estimation were made following the steps suggested in the IDEAS - General Guidelines for the Estimation of the Committed Effective Dose from Incorporation Monitoring Data. The values determined for the efficiency (E) and for the Minimum Detectable Amount (MDA) for probe were of $3.76 \times 10^3 \pm 1.15 \times 10^4$ CPS/Bq and 46 Bq for $^{131}$I (364 keV), respectively. Meanwhile, for the gamma camera with pinhole were significant higher (E = $1.96 \times 10^4 \pm 9.3 \times 10^6$ CPS/Bq and MDA=85 Bq). The probe system is capable to detect dose as low as 0.004mSv at 24h and 0.02mSv at 2h. A worker monitoring $^{131}$I intakes procedure was proposed and established, based on routine screening 2 and 24 hours after to finish “hot lab”, “administration routine” of $^{131}$I dose to patient, contaminated wastes manipulations, or in case of detected or suspected radionuclide intake. If the contamination is positive, confirmatory monitoring should be developed using the “probe” (and the gamma camera if it is needed for spatial thyroids uptake distribution). The committed equivalent thyroid dose will be evaluated taking into account the real thyroid mass, using the up-taking mass correlated with ultrasound and the real bio-kinetic behavior. The use of probe, for this purpose, produces a significant reduction of uncertain caused by the mass of thyroid, effective half-time and the time of intake. Also, it includes the possibility to block the thyroid uptake during the first 4h of intake, with the reduction of the Committed Effective Dose and Committed Equivalent Dose of the worker.

Index Terms: radiation worker’s surveillance, internal contamination, I-131 intake, nuclear medicine workers

Geant4 application for electron beam quality in Intra-Operative Radiotherapy based on simulation of the linear accelerator Novac11

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Intra-Operative radiotherapy (IORT) is a very effective technique that has begun to be used in our region. It has proven to be a good alternative as part of the breast conserving surgery. Technical success is based on the administration of high doses to the lesion in a single treatment session of radiotherapy, during the same surgical operation, with multiple clinical advantages that are not exempt of risk and must be evaluated deliberately. In this work, a specific application of Geant4 was created to allow IORT dose calculations to be assessed using Monte Carlo (MC) simulations with acceptable accuracy for dose prediction in complicated treatment plans and also to estimate radiation dispersed in the operating room. The application simulates the irradiation head of the linear accelerator Novac11 in different positions with different types of applicators. The Monte Carlo simulation was preliminarily validated by comparing the simulated dose distributions with the measurements by means of the ionization chamber in a water phantom.
Implementation of “S factor methods” for 3D dose planning in ¹³¹I hyperthyroidism treatment

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The optimization of patient-specific treatment planning of hyperthyroidism with ¹³¹I is a desirable goal from medical and radiation protection point of view. The purpose of this work was to develop a software based on MATLAB, capable to handle non-uniform activity distribution at voxel level and made dosimetry calculation using the “S” factor from MIRD methodology, planning the therapeutic activity (TA) to warranty the prescribed treatment dose (DP), using a nuclear medicine multitechnology approach.

To verify the developed tool, the results of 6 patients dose therapy planning with theoretical 1D, theoretical 3D and “S” factors using SPECT and ¹³¹I biokinetics were compared (DP between 150-400Gy).

The discrepancy between the two 3D methods concerning to the thyroids average dose among prescribed dose were less than 10%, showing the system capability to proper dosimetry calculation. The 3D dose distribution dissimilarities between “S” factors and theoretical methods took the maximum value of 23% (voxel to voxel dose value / DP), near to the thyroids boundaries tissue. Despite of those difference is inside the typical uncertain range of dose determination methods; the issue should be study deeply using Monte Carlo (MC) approach in order to clarify the voxel dose accuracy of the two methods.

Conclusion: The 3D treatment planned dose distributions were completely no-homogenous, the significant difference observed between voxels should be study in order to optimized the hyperthyroidism iodine treatment.

Index Terms: optimization, patient’s specific treatment, I-131, Hyperthyroidism

In Vivo Dosimetry in Total Body Irradiation

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Total Body Irradiation (TBI) is a radiotherapy technique that consists of irradiating homogeneously the whole patients body and it is characterized by extended source to surface distances and the use of large irradiation fields. The limitations of the available input data and inherent problems with the calculation procedures make it very difficult to accurately determine the dose distributions in TBI. For these reasons, it is highly recommended to use In Vivo Dosimetry (IVD), to guarantee the quality of TBI treatments as a direct measurement of the delivered dose. An IVD QA system was implemented based on semiconductor diodes and radiochromic films. For the commissioning of the system, both detector types were calibrated independently, using as reference an ionization chamber with a valid certificate in terms of absorbed dose to water (Dw). This guarantees the traceability of the measurements. An assessment was made on the sources of uncertainties. A tolerance level of ±10% was established for the combined contribution of both computational and experimental uncertainties. An experiment was carried out to simulate a clinical TBI procedure to a phantom. In this way, the calibration of the dosimetry system was corroborated. Finally, the IVD system was applied in TBI of three real patients. The discrepancies obtained between the prescribed and measured doses were below the established tolerance level of ±10 %.
Incidence of medical physic in prevention of radiological accidents with patients

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In radiotherapy and nuclear medicine processes, medical physic have a preponderant participation in the correct administration of prescript doses to a patient, so that if they differ more than a predetermined value to the prescription, become in radiological accident or a mistreatment.

In this paper is exposed a quantitative and qualitative analysis, based on Risk Matrix Method, particularly for external radiotherapy with cobalt radioactive source and nuclear medicine including metabolic therapy with radioactive iodine $^{131}$I, and on the functions assigned in Regulatory Safety Guides for both practices to the medical physic in Cuba of the incidence of this professional in prevention and escalation of this sort of accident, playing a roll of barrier and of their frequency and consequences reductor.

As results, it is shown the relevance and need of safety approach that must prevail for this professional as much in his education as in its daily work and in the education and control of the other personnel in these services as well.

Interaction analysis between polyvinylpyrrolidone (pvp) nanogels synthesized by gamma radiation and human neutrophils

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Nanogels are extensively studied for diverse biomedical applications. One of the most relevant is the use as drugs nano-carriers for therapeutic purposes, increasing the bioactivity and transport of active components to specific sites or cells. Nanogels-based drug release formulations improve the effectiveness and safety of certain anticancer drugs and radiopharmaceuticals, minimizing its delivery and tumor accumulation problems associated with the existing traditional nuclear medicine agents. In the present work, the interaction of 30 nm Polyvinylpyrrolidone (PVP) nanogels with human neutrophils cells was evaluated. The analysis was performed using Nitroblue Tetrazolium microscopic and colorimetric assay, as an attempt to achieve the more comprehensive view of nanogel interaction with the main cells of the innate immune system. PVP nanogels synthesized by gamma radiation, and titanium oxide nanoparticles exhibited similar cellular activation through the low production of Reactive Oxygen Species (ROS). In contrast, PVP nanogels showed less cellular activation compared to the bacterial peptide fMLP. This result suggests PVP nanogels as good candidates for drug delivery systems.

Keywords: PVP nanogels, neutrophils, Nitroblue Tetrazolium, drug delivery systems

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Investigating flattening filter free mode for peripheral lung stereotactic body radiation therapy

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Purpose: The flattening filter free (FFF) mode (Elekta) was recently installed at our institution. We investigated FFF planning and delivery for stereotactic peripheral lung treatment as the increased dose rate of FFF mode can reduce the treatment time.

Methods: Ten lung cancer patients with peripheral lesions previously treated with VMAT SBRT were selected to span a range of target sizes and locations. Three additional plans were created for each patient: two 3D conformal plans with 6 MV conventional flattening filter (cFF) and FFF beams, and a...
VMAT plan with 6 MV FFF. Beam on time was measured for the VMAT plans and estimated for the 3D conformal plans.

Results: FFF VMAT plans met our institutional planning criteria with no or minimal changes to the optimization parameters. The FFF VMAT plans required 5.0 minutes less (median) delivery time (range 2.3 to 10.1 min) compared to cFF VMAT plans. The median effective dose rate for cFF VMAT was 533 MU/min (range 510-562) and for FFF VMAT was 1144 MU/min (range 934-1406) compared to maximum dose rates of 590 MU/min and 1550 MU/min respectively. FFF conformal plans met planning criteria and had an estimated median time savings of 2.5 min (range 2.0-3.3) compared to conformal plans using the cFF beam.

Conclusions: Acceptable peripheral lung SBRT plans can be produced with the FFF beam using both 3D conformal and VMAT techniques. Median time savings of 5.0 and 2.5 minutes for VMAT and 3D conformal plans were achieved compared to using the cFF beam.

Poster Session - MP / 86

Method for noise reduction in Computed Tomography images with an approximate bilateral filter

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Despite the clear evidence that computed tomography provides very valuable information for diagnosis, there is a potential risk for the use of ionizing radiation. In CT, decreasing the dose of radiation increases the amount of noise in the images; therefore, the noise can hide anatomical details and decrease the detection of injuries. The Bilateral filter, proposed by Tomasi and Manduchi, is able to preserve the edges of the image and to reduce noise in uniform regions. The ability of the BF to reduce noise depends on the function of two sub-factors including spatial distance and intensity weights. In the BF the functions of these weights are exponential. This function has the advantage of reducing the greater amount of noise and better preserving the structural details. The disadvantage is that this noise reduction and detail preservation capability decreases after a certain noise value by reducing filter performance. The advantages of this feature have a very narrow margin and can easily be lost in practical applications where noise variability increases. This affects the performance of the BF causing blurring in the details of the image and a decrease in the ability to reduce noise in the image. In order to be more effective the filtering process in our work, we made a reformulation of the sub-factors of spatial distance and intensity. The function exponential of these sub-factors was approximated to fractional through the MacLaurin serial development. The reformulation, guarantees a better stability in the noise reduction capacity, a better preservation of details in the image when there is an increase in noise variability as well as a reduction in the execution time.

Poster Session - MP / 160

Modeling an Elekta Precise linac head using the Monte Carlo code GATE

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The Monte Carlo method (MC) has been commonly used in medical physics applications such as radiotherapy, radiation protection and nuclear medicine due to the stochastic nature of radiation and detection processes. In our country, during the last few years, new radiotherapy machines with novel technological advances have been acquired. Among this new equipment, the linear accelerator (linac) has the capability to deliver treatment techniques with high level of complexity. In order to be capable to perform several research activities with a direct impact on the daily clinic our first step was to model the linac head of an Elekta Precise that is commonly used in radiotherapy facilities in Cuba. The MC code employed was GATE, which uses GEANT4 libraries and was adapted for easy implementation in the field of radiotherapy and nuclear medicine. To validate this geometrical model several calculations on a water cube were performed. For each simulation a dose image was obtained. Each dose image was compared with experimental data provided by the medical physics group from the radiotherapy department of the Oncology Institute at Havana using the same beam set up: Source Surface Distance (SSD), Energy, and field sizes of 5x5 cm², 10x10 cm², and 20x20 cm². The uncertainty obtained for each simulation was of 2% for each dose image and the standard deviation with measurements was 3%.
Modeling of normal tissue complication probability estimation in normo and hypo-fractionated radiotherapy of head & neck tumors

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Hypo-fractionation requires consistent iso-effect dose calculations and the linear-quadratic (LQ) formalism is appropriated for these analysis. Dose magnitudes with “biological sense” like Equivalent Uniform Dose (either physical EUD or biologically effective EUBED) will improve the predictions made with models for Normal Tissue Complication Probability (NTCP) calculation and also facilitates the iso-effects analysis for the Organs at Risk (OARs). The goal of the present work is to evaluate the differences in the estimation of NTCP for hypo-fractionated treatment in radiotherapy of Head & Neck (H&N) tumors compared with the normo-fractionation schedule. Radiobiological parameters variability, heterogeneity of spatial dose distribution and the influence of gEUD (generalized Nimierko’s model), EUBED or mean BED in the NTCP estimations were considered. The dose distribution data were obtained from real treatment plans: normo-fractionated group: 66Gy in 33 fractions and hypo-fractionated group: 55Gy in 20 fractions giving 2.75Gy/ fraction with 5 fraction/week for both branches. The dose-volume histograms (DVHs) for the spinal cord, brainstem, right and left parotids, pharynx and esophagus were built. The NTCP (LKB and Källman’s relative seriality models) was estimated as function of gEUD, mean BED or EUBED. An average DVH was also estimated by averaging the volume fractions, which receives the same dose interval for a given OAR and the NTCP values with both response models were estimated. The ranking of the models was based on Akaike's information criterion (AIC). The variability of alpha/beta in the calculation of NTCP produces curves less steep than those when a fixed alpha/beta value is used. The effect increases as alpha/beta is diminished and it was also observed for both branches. Similar effects have been described for tumor control curves, which must be included in the algorithm for biological evaluation of radiotherapy plans. There were no significant differences between the calculations done with the NTCP models used considering the AIC calculation. The mean BED produced a similar description than those made with EUD or EUBED even considering the differences in the consideration of volume effects. It was obtained a formulation for biological evaluation of hypo-fractionated treatment plans.

Modelling of an Apex Microcollimator coupled with a Precise linear accelerator for radiosurgery treatments

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Sophisticated devices are used in Stereotactic Radiosurgery (SRS) for delivering small radiation beams in specific geometries. Computer planning systems are customized with specific dosimetric data corresponding to the specific machine.

At Instituto Nacional de Oncología y Radiobiología, an Apex micro multileafs collimator was adopted together with an Elekta Precise linear accelerator for SRS treatments. The system’s dosimetric characteristics were measured, according to the manufacturer’s recommendations for modelling the beam in a Monaco Treatment Planning System (TPS). The beam production and delivery system is not usual and its measurements are also of interest for small fields dosimetry research.

Measurements were carried out with three dosimetric systems, generally considered as suitable for small fields dosimetry as found in SRS. A Pin Point ionization chamber, a diode and a diamond dosimeter, all from PTW, were used in combination with a 3D water phantom and Mephysto software, also from PTW. Output Factors, depth dose curves and profiles were measured at different depths. In this work, measurements results and comparisons among them are presented. In order to conform the beam model,
the data gathered with the diode was selected. For very small fields was, the chamber’s results diverged from those of the other systems, as previously seen in other works. With this work’s results, the Apex radiation beam model could be modeled and the Monaco TPS will have the capacity to calculate SRS treatments. Besides, results from these measurements contribute to the international research project related to small beam dosimetry.

**Poster Session - MP / 166**

**Pilot testing of the new IAEA/AAPM Small Field Code of Practice**

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**Poster Session - MP / 125**

**Plasma dynamic viscosity determined by NMR**

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**Poster Session - MP / 125**

**Plasma dynamic viscosity determined by NMR**

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**Poster Session - MP / 125**

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**Poster Session - MP / 125**

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A NMR based experimental procedure to determine the dynamic viscosity in Plasma solutions is presented. An equation relating and the transversal proton magnetic relaxation time ($T_2$) is obtained after considering a fast exchange between the free and associated water inside the Plasma Solution, the dominant role of the associated water in proton magnetic relaxation, the characteristic mobility of the plasma proteins and the magnetic field value used in the experiment. Carr-Purcell-Meiboom-Gill pulse sequence was used to measure $T_2$ in a magnetic resonance console coupled to one homogeneous magnetic system (0.095 T). A value of 1.66 ± 0.05 mPas was obtained in 27 controls individuals, which statistically match with the value obtained in the same samples using the Oswald viscometer (1.62 ± 0.03 mPas) was determined in 166 patients with Multiple Myeloma (2.24 ± 0.07 mPas) and 54 with Sickle Cell Disease (1.92 ± 0.05 mPas) showing an statistically significant increase over the control individuals. The results show the utility of this NMR method to estimate dynamic viscosity in Plasma with medical purpose.

**Key words:** Dynamic viscosity, Transversal relaxation time, Plasma, Multiple Myeloma, Sickle Cell Disease.
Quality Assurance for CO60 HDR Brachytherapy

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A quality assurance device for source position in HDR remote after loaders with Co60 sources was investigated. A cerrobend materials insert, consisted in a cylinder with a transverse spacer of acrylic at a precisely known distance from the source, was constructed and tested. Several sizes of the acrylic window, dwell position and steps were optimized in order to determine the response of the detector to the signal. The current shape curve and maximum was well reproduced for several windows and the 5 mm size was selected for an optimal measurement when the background with no window was subtracted. This method allows determining the source position better than ±2 mm accuracy. This methodology may provide an easy way to periodically check source position accuracy for HDR Co-60 sources in brachytherapy, in a similar way as the SI-HDR-1000 QA Tool allows to do for Ir-192 sources.

Study by Monte Carlo method of cross radiation in the bimodal tomographic system ClearPET/XPAD3-CT

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A detailed simulation of cross radiation in the PET and CT detectors of the tomographic bimodal system for small animals ClearPET/XPAD3-CT, was made using the Geant4 Monte Carlo code. A positron emitter radioactive point source (FDG-18F) was located in the center of the tomographic system, inside a spherical water phantom. Positron-electron annihilations occurring within the phantom produce gamma photons that arrive both to PET (phoswich) and CT(XPAD3) detectors. Simultaneously X-ray photons from the generator tube, oriented towards the XPAD3 detector are scattered by the phantom, arriving to the phoswich detector. Therefore, we have in both detectors undesired incident radiation coming from the other system. From this study conclude that cross gamma rays contribute about 3.5% of the total intensity in the XPAD3 detector, while cross X rays arriving to the phoswich detector contribute about 3.0% of the total intensity, which is actually reduced to below the noise level, taking into account a Cu filter layer of 0.5mm, which covers these detectors. In this work, it is proposed to optimize the shielding of the system without impairing the efficiency of the detectors.

Study of angular dependence in Fiber Optic Dosimetry by Monte Carlo simulations

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Real-time dosimetry for radiotherapy with high spatial resolution is a growing research field. Development of new radiotherapy techniques, such as intensity-modulated radiation therapy, stereotactic radiosurgery,
and high dose rate brachytherapy among others, require high performance dosimetrics techniques. Even though different kinds of detection systems have been investigated to perform in-vivo dosimetry, most of them do not permit simultaneously spatial resolution, real-time dose assessment and intracavitary measurements.

The so-called fiberoptic dosimetry (FOD) technique has shown to meet most of these requirements mostly needed in radiotherapy [1]. FOD is based on the use of a tiny piece of a scintillation crystal (1mm³ aprox) attached to the end of an optical fiber [1]. The fiber collects the light emitted by the scintillator during irradiation (radioluminescence, RL) and a light detector at the other end of the optical fiber measures its intensity. FOD technique allows for in-vivo and real-time dose assessment, and due to the small size of the detector it not only permit accurate measurements in regions of high dose gradients but also intracavitary measurements [2].

Martinez et al. [3] observed angular dependency of the scintillating signal when cylindrical detectors are employed as usual in this technique.

In the present work, we study the angular response of a YVO₄:Eu³⁺ based FOD probe by using Monte Carlo simulations in order to explain the different attenuation process. Two geometrical configurations have been studied: 1mm diameter spherically shaped detector, and 2mm length-1mm diameter cylindrical detector. Simulations have been achieved by using PENEOPE employing an hybrid virtual source model based on IAEA phase space data base. In both cases results have been compared with experimental measurements.


Poster Session - MP / 75
The association of CT dosimetric quantities with clinical operational factors: basis for specific optimization strategies

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The motivation of this analysis was the knowledge of quantitative association between CT dosimetric quantities and operational factors and devise scanner-specific optimization strategies. The measure of indexes of kerma free in air and in standard phantoms (in a Siemens Sensation CT scanner) provided the main data for identification of statistical associations with operational factors and x-ray spectrum estimation. The association between the CT air kerma index free in air at isocenter, and the x-ray-tube potential, corresponds to a power law function with power coefficients of 1.65 – 2.80 in average, for different combinations of tube current time product and total collimation. The average kerma quantity for the periphery of the standard CT dosimetry phantom was linearly associated with the CT air kerma index measured at the center of the same phantom. The linear model parameters were 1.05 and 1.91 in average for standard phantoms with diameters of 160 and 320 mm respectively. The was associated linearly with its primary component, the latter estimated by attenuating the computed primary x-ray spectrum, with constant total collimation for each case. The equivalent water diameter estimated was into a range of 67 – 75 mm and 136 – 144 mm among all operational factor combinations for standard phantoms of 160 and 320 mm respectively. This allows gaining insight into its association with dosimetric quantities for optimization purposes. The descriptive analysis of CT dosimetric quantities and its association with clinical operational factors allows gaining insight in the ability to devise model based optimization strategies.
Theoretical and Monte Carlo simulation approaches for X-ray production in different anode geometries

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The traditional scheme for X-ray production is based on the well known X-ray tube, an evolution in technology started from the experiments performed by Crookes and finally by X-rays discovery by W. Röntgen in 1895. As known, X-ray tubes are mainly based on the impact of accelerated electron onto high atomic number anodes in order to produce photons by means of Bremsstrahlung and characteristic X-rays. However, spectral and angular distributions of produced photons may not be strictly improved, or even worst, not adequate for specific applications. Actually, one of the main properties of traditional X-ray tubes regards its geometrical divergence, which necessary produces fluence reduction along beam trajectory. This inherent characteristic represents a strong limitation when high concentrated fluence is required, as happens in convergent techniques [1]. This work presents investigations about the effects of the different anode properties in combination with electron beam incidence in order to assess convenient X-ray tube designs to produce X-rays with different purposes, mainly focused on applications requiring photon fluence concentration. Dedicated Monte Carlo subroutines (PENELOPE [2] and FLUKA [3]) were developed aimed at describing inter-action processes and X-ray production according to different combination of electron beam incidence and anode physical/geometrical properties. The obtained results confirm that suitable designs are capable of improving photon fluence at certain regions according to specific requirements.


The FLUKA code: Description and benchmarking, AIP Conf. Proc. 896, 31-49.

Keywords: X-ray production; Convergent photon beam; Monte Carlo simulation.

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Verification of angular dependence in MOSFET detector

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In vivo dosimetry is an essential tool for quality assurance programs, being a procedure commonly performed with thermoluminescent dosimeters (TLDs) or diodes. However, a type of dosimeter that has increasing popularity in recent years is metal-oxide-semiconductor field effect transistor (MOSFET) detector. MOSFET dosimeters fulfill all the necessary characteristics to realize a in vivo dosimetry, since it has small size, good precision and feasibility of measurement, as well as easy handling. Nevertheless, its true differential is to allows reading of the dose in real time, enabling immediate intervention in the correction of physical parameters deviations and anticipation of small anatomical changes in patient during treatment. In order for the MOSFET dosimeter to be better accepted in clinical routine, informations related to its performance should be available frequently. For this reason, this work proposes to verify reproducibility and angular dependence of the standard sensitivity MOSFET dosimeter (TN-502RD-H) for Cs-137 and Co-60 sources. Experimental data were satisfactory and MOSFET dosimeter presented a reproducibility of 3.3% and 2.7% (1 SD) for Cs-137 and Co-60 sources, respectively. In addition, an angular dependence of up to 6.1% and 16.3% for both radioactive sources, respectively. It is conclusive that MOSFET dosimeter TN-502RD-H has satisfactory reproducibility and angular dependence. This means that although precise measurements, special attention must be taken for applications in certain anatomical regions in patient.

Poster Session - MP / 187

Verification of angular dependence in MOSFET detector

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