Abstracts of the 53es Journées Scientifiques de la Société Française de Physique Médicale

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CONTENTS

Abstracts of the 53\textsuperscript{es} Journées Scientifiques de la Société Française de Physique Médicale
4-6\textsuperscript{th} June 2014, Deauville, France

SESSION: IMAGE GUIDED RADIOTHERAPY e123
SESSION: RADIOLOGY e125
SESSION: QUALITY CONTROL IN RADIOTHERAPY e131
SESSION: NUCLEAR MEDICINE e133
SESSION: HADRONTHERAPY e134
SESSION: STEREOTAXY e135
SESSION: QUALITY CONTROL - RISK MANAGEMENT e139
SESSION: RADIOTHERAPY (TRANSIT DOSIMETRY, QUALITY CONTROL OF TREATMENT PLANS) e140
Aims and Scope

- **Medical Imaging**
  - Physics in medical imaging
  - Image processing
  - Medical acoustics and ultrasound
- **Radiation Therapy**
  - Physics in radiation oncology
  - Radiation dosimetry
  - Laser applications in medicine
- **Radiation Protection**
  - Ionising and non-ionising radiation protection
  - Biological effects of ionising and non-ionising radiation

Contributions on other topics related to Applications of Physics to Biology and Medicine and in particular related to new emerging fields such as Molecular Imaging, Hadrontherapy, System biology, Nanoparticles and Nanotechnologies, etc. are strongly encouraged.

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FEASIBILITY OF IMAGE GUIDED RADIOTHERAPY BASED ON ULTRASOUND MODALITY FOR PROSTATE INTER AND INTRA FRACTION MOTION

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Background: Various invasive and/or irradiating tracking techniques are proposed for monitoring target motion during radiotherapy sessions. Ultrasound (US) based imaging could be a better alternative for prostate cancer because it offers good soft tissue contrast, without additional dose or any invasive act. This work reports preliminary results of inter and intra fraction motion measurements on prostate cancer patients.

Materials and methods: 2 patients irradiated with an intact prostate (groupe A) and 7 patients irradiated after a prostatectomy (groupe B) were imaged using a transperineal (TP) ultrasound probe (Clarity Autoscan, Elekta) during the CT session (USref) and just before each treatment session (USdaily). The US device enables the acquisition of 3D images using a continuous motorized sweeping of the region of interest, and the quantification of the motion during the irradiation thanks to an automated algorithm. For each treatment session, an US daily image was acquired previously to a Cone-Beam CT (CBCT) image. Patient repositioning was always performed based on the CBCT/CT registration. Inter fraction motions, measured using USdaily/USref and CBCT/CT registrations, were always performed based on the CBCT/CT registration. Intra fraction motions (USdaily) were analyzed to calculate the treatment setup.

Results: No TP-US image was excluded from the analysis because of insufficient quality. Comparison of inter-fraction shifts showed that mean differences were below 2 mm for both groups and all directions. Shifts agreements between the 2 modalities were above 97.5 % for both groups and all directions, except in the supero-inferior direction for the group B (85.7%). Observation of the intrafraction motion showed larger shifts in the antero-posterior direction with up to 35% of fraction having shifts above 3 mm.

Conclusion: A good correlation was observed between interfraction shifts obtained by TP-US and CBCT modalities for both prostate and post-prostatectomy patients. Motions up to 8 mm were observed during intra-fraction monitoring. Accrual of patients is in progress to assess these first observations.

Keywords: IGRT, Prostate, Ultrasound

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ADAPTATION OF TREATMENT MARGINS FOR HYPOFRACTIONATED RADIOTHERAPY OF PROSTATE CANCER

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Context: The emergence of hypofractionated treatment requires a better accuracy in the dose delivery because of an increased toxicity on the safe tissues. In particular for prostate cancer, treatment margins reduction could significantly decrease the risk of toxicity on the organs at risk (OARs) considering intra-fraction prostate motions. The aim of this study was to assess which margins were more appropriated in function of the dose per fraction and volumetric modulated arc therapy (VMAT) treatment duration.

Materials and methods: A dosimetric study was performed for 1 patient treated with VMAT using the Monaco treatment planning system (Elekta). Three different protocols were used: 80 Gy (2 Gy/fraction); 60 Gy (3 Gy/fraction) and 36.25 Gy (7.25 Gy/fraction). For each treatment, 3 different planning target volumes (PTV) were generated by adding margins of 7, 5 and 3 mm to the prostate volume in order to evaluate the dosimetric impact of a PTV margin reduction on the dose to the OARs and PTVs. Hence, 9 treatment plans were made. The treatment durations delivered by a linear accelerator Synergy (Elekta) were then measured. In parallel, intrafraction motion of 5 patients imaged with Autoscan ultrasound system (Clarity, Elekta) were analyzed to calculate the treatment margins adapted to each protocol.

Results: A margin decrease of 4 mm allowed to gain up to 5% and 2.5 Gy in terms of PTV coverage and mean dose to the OARs, respectively. The average treatment durations were 90, 200 and 240s for delivering 2, 3 and 7.25 Gy, respectively. The margins based on intra-fraction motions observed during these treatment durations were 1.21, 1.47 and 1.57 mm in the superior-inferior direction, 1.01, 1.20, 1.26 mm in the right-left direction and 1.08, 1.18 and 1.22 mm in the anterior-posterior direction, for doses per fraction of 2, 3 and 7.25 Gy per fraction, respectively.

Conclusion: Hypofractionated treatments need a margin reduction to improve the dosimetry quality. The optimization of these margins requires a proper consideration of the treatment duration.
EVALUATION OF TARGETING ACCURACY DURING A FRAMELESS STEREOTACTIC LUNG TREATMENT USING RESPIRATION CORRELATED CONE-BEAM CT IMAGE GUIDANCE

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Introduction: The purpose of the study was to assess target localization accuracy in stereotactic body radiation therapy (SBRT) of lung lesions using an image-guidance process based on respiration correlated cone-beam computed tomography (4D-CBCT) and validate the planning target volume (PTV) margins.

Materials and methods: The study was performed for 15 patients with inoperable lung lesion treated by IMRT on an Elekta Synergy treatment unit equipped with 4D-CBCT Symmetry™ option. No stereotatic body frame was used. The PTV was defined by adding a 4-mm margin to an internal target volume (ITV) created from a four-dimensional computed tomography (4D-CT) (Philips Brilliance Big Bore). For each fraction, a 4D-CBCT scan was acquired to measure and correct the time-weighted mean tumor position. A standard CBCT was acquired just before and just after treatment delivery to assess the intra fractional stability of the target during fraction delivery. Retrospectively for each patient the tumor was delineated on each CBCT on a Philips Pinnacle workstation.

Results: i) The accuracy of target localization with 4D-CBCT was evaluated after registration by calculating residual deviation of the mean tumor position relative to its planned position; ii) the displacement of the target during dose delivery was quantified by comparing mean tumor position before and after the dose delivery; iii) the coverage of the target by the PTV was calculated by generating a map of presence probability of the target during treatment.

Conclusion: With 4D-CBCT image-guidance, SBRT in lung can be safely administered with setup margins below 5 mm without using dedicated stereotactic body frame.

Keywords: 4D; CBCT; Respiratory management

POSTERS

P-01.
CBCT-IGRT USE TO IMPLEMENT ADAPTATIVE TREATMENT: COMPARATIVE STUDY OF CT- AND CBCT-BASED DOSIMETRIES USING THE CIRS PHANTOM AND THE GAMMA INDEX

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Introduction: IGRT provides informations about the positioning of the patient, tumor and organs at risk evolution, compared to the reference CT exam. Some anatomical, biological and functional changes can be observed during the treatment. The CBCT images can thus be used to recalculate the dosimetry and assess the real delivered dose throughout the treatment, providing a supplementary help to decide for a replanification on a new CT exam (ART) or for a retrospective assessment (cumulative dose).

Material and method: The use of CBCT images for dosimetry calculation requires a CT-number versus density calibration curve. The implementation of this calibration curve on our XVI system 4.5 (Elekta Agility) was performed in Pinnacle 9.2 by using the phantom CIRS (Model 062MA CBCT). This CIRS phantom was also used for testing the dosimetry quality. Different types of plans (3DRT, VMAT) and different localisations (Head&Neck, prostate etc.) are calculated from the CIRS and re-computed on the CIRS CBCT for comparison. Many parameters are available to compare CT and CBCT dosimetries. Nevertheless some of them could be sensitive to geometric considerations (position, contouring) and may not be so representative. Using the gamma index as a comparison parameter offers interesting possibilities in dose quality assessment.

Results: The comparison of CT-based and CBCT-based dosimetries, whatever localisation and plan for the CIRS, shows that more than 95 % of the considered voxels pass the criteria of 2mm and 2%. Nevertheless, one has to pay attention for lung or dense bone similar tissues that could have 5% difference locally observed when the mean dose parameter is used. For clinical cases (3DRT plan), recalculation on the CBCT images, shows a mean dose difference of 0.5% for the PTV, 1.6% for the rectum and 3% for the femoral heads (prostate). One H&N exception is observed for one XVI acquisition with a difference of 3.8% for the PTV.

Conclusion: CBCT can be used to re-planning a dosimetry and evaluate the effect of movement or shrinkage changes during treatment. It is a relevant tool to decide for a replanification based on a new CT scan with a secure threshold >5% for dose difference.
P-02. DELIVERED DOSE DISTRIBUTION IN PATIENT FROM KV-CBCT, XVI ELEKTA SYSTEM
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Introduction: The objectives are to quantify the additional dose distribution delivered by KV-ConeBeam Computed Tomography (kV-CBCT) with ThermoLuminescent Detector (TLD) inserted into an anthropomorphic phantom and to measure in-vivo dose on patient during kV-CBCT acquisition with MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

Materials and methods: kV-CBCT acquisitions (XVI Synergy; Elekta) for localizations Brain (70kV ; 18,3mAs ; SFOV), Head & Neck (100kV ; 18,3mAs ; SFOV), Prostate (120kV ; 1056mAs ; MFOV) were performed on an adult anthropomorphic phantom (Rando; Anderson). To determine slice dose distribution for all 3 localizations TLD (GR200A, Fimel) were enabled dose measurement in different positions on the phantom’s surface and on 20 patients (10 prostate patients, 5 Head & Neck patients, 5 Brain patients).

Results: Dose distribution is not uniform within a slice. Doses on phantom’s surface layers, especially on clinical risk zones: eyeballs and lens for Brain, thyroid gland, parotids and acoustic canal for Head & Neck, testicles and rectum for Prostate. The slice measurements are coherent with displayed Computed Tomography Dose Index volume (CTDVol) but do not correspond to organ dose. The measurement accuracy is 0,04mGy for TLD, 0,32mGy for MOSFET. MOSFET measurements are not significant for doses below 0,5 mGy, this limits their clinical use for Brain cases (CTDVol 0,3mGy). On the phantom, maximal relative deviation between MOSFET and TLD measurements is 13% for Prostate localization (CTDVol 22mGy) and 20% for Head & Neck localization (CTDVol 0,6mGy). On 20 patients, the MOSFET measurement statistical dispersion is coherent with one on phantom. The maximal relative standard deviations on phantom and patients are respectively 5% and 7% for Prostate localization, 14% and 17% for Head & Neck localization.

Conclusion: During kV-CBCT acquisition protocols, MOSFETs are a good alternative for in-vivo patient dosimetry for some surface organs, relevant for Head & Neck and Prostate localizations.

Keywords: kV-CBCT, Dose distribution, MOSFET

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P-03. A FOUR-YEAR COMPREHENSIVE ANALYSIS OF RANDOM AND SYSTEMATIC ERROR DISTRIBUTION IN A RT CENTRE RUNNING TWO LINACS EQUIPPED WITH KV-CBCT
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Introduction: Online image guidance in treatment position provides useful information with respect to various sources of error that may jeopardize treatment accuracy. Registration procedures (CBCT to reference CT) and safety margins (CTV to PTV expansion) can be evaluated by means of statistically significant geometrical data collected over time.

Materials and methods: Kilo-voltage Cone-Beam CT (kV-CBCT) image reconstruction and registration were achieved using XVI software, version 4.2.1 (Elekta Oncology Systems, Crawley, UK). Since 2010, we have calculated systematic and random errors for more than 23000 CBCT acquisitions (69000 translation errors). Based on van Herk’s work, we compared our group systematic and random errors to published data, for three tumour localizations (prostate, head-and-neck and lung). We also assessed our routine margins using van Herk’s margin recipe. Finally we tried to explain abnormally high position errors (larger than 2 cm) occurring from time to time.

Results: With regard to published data (i.e. systematic and random errors around 1 mm, 2 mm, and 3 mm for head-and-neck, prostate and lung, respectively), our results are globally larger, especially for head-and-neck patients. Comparing to safe margin recipe, our margins are too short in view of treating patients without daily image guidance, except for prostate patients. Regarding outliers (errors larger than 2 cm), manipulation errors were identified in most cases and were related to wrong table displacements starting from skin marks.

Conclusion: Statistical analysis of patient position errors proved to be very instructive with regard to accuracy and reproducibility of treatments (immobilization systems, margins, human errors). Benchmarking of the results allowed us to draw interesting conclusions and to initiate further investigation. However, clear identification of the origin of inaccuracies is very difficult (patient preparation, immobilization system, spatial registration, anatomical changes, etc…).

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SESSION: RADIOLOGY

ORAL COMMUNICATIONS
DESIGN AND SET-UP OF AN AUTOMATIC QUALITY CONTROL PROCEDURE IN MAGNETIC RESONANCE IMAGING
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Introduction: Magnetic Resonance Imaging (MRI) is commonly associated with other medical imaging modalities. MRI is used for quantitative studies and its technology is getting more complex with the growing use of phased-array coils. These reasons partly motivate the rising need for quality assurance. Indeed, it is important to monitor the performance of clinical MR scanners in order to avoid possible diagnostic errors.

Purpose: To design and to set a MRI quality control (QC) methodology which is required to be practical, time-consuming, statistically robust and vendor-independent (thus compatible with different scanners).

Material and methods: The designed weekly QC procedure was based on the standards of the American College of Radiology which recommends a single phantom for measuring different metrics. The longitudinal follow-up of these metrics enables to understand the stability of the MR scanners. We made remarkable developments to the main parts of the procedure: image acquisition, image processing, statistical analysis, and the production of performance reports. Ultimately, the weekly QC procedure includes a less-than-10-minute acquisition protocol (performed by the MR technologists), an automatic image analysis protocol, a routine statistical analysis of the metrics, and a semi-automatic production of performance reports. This weekly QC procedure was successfully validated through testing on several MRI scanners (one 3T and five 1.5T) by using head coils, these latter being perfectly suited to the phantom’s size.

Results – discussion: Automating the image analysis operations enabled to enhance the accuracy and the reproducibility of the measurements. The QC metrics provided by this procedure revealed to be useful and relevant for monitoring MRI scanners. Besides, the metrics are pertinent for performing objective comparison of different scanners.

Conclusion: The MRI technologists are strongly associated to the process of performing this quality control procedure. The procedure is highly concise thus it is easy and practical to be implemented in a MRI service. The automatic image analysis software enables to yield reliable and reproducible results. Consequently, our QC procedure can fit well to any quality assurance program related to clinical MRI.

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IMPACT OF THE RECONSTRUCTION PLAN ON IMAGE QUALITY FOR CT IMAGES
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Introduction: Images acquired with Computed Tomography (CT) are traditionally reconstructed and interpreted in the axial plan. However, in clinical practice there are several situations where images have to be visualised in the axial, sagittal and coronal plan. Moreover, recent introduction of iterative algorithms allowed a significant diminish of the delivered dose, but this also goes along with repercussions on image quality. This impact has been widely studied in the axial plan but work still needs to be done for the coronal and sagittal plan.

Material and method: Images were acquired on a HD 750 GE CT, in the 3 plans and with a CTDIvol of 7.3mGy. Each acquisition was reconstructed with a bone filter, as well as different reconstruction algorithms: the classical Filtered Back Projection (FBP) and iterative algorithms (ASIR (40% and 80%) and MBIR). Image quality assessment was done using phantoms. The MTF (Modulation Transfer Function) and the NPS (Noise Power Spectrum) were calculated in order to estimate the noise as well as the spatial resolution of the images. Image quality was also assessed through an additional metric called Task Transfer Function (TTF). It was estimated using a phantom containing cylindrical inserts composed of materials surrounded by water. TTF is obtained by measuring contrast difference between the inserts and the water and then applying mathematical treatment to the data. This allows us to estimate spatial resolution when taking contrast transfer into account.

Results: Results show that images acquired and reconstructed in the same plan exhibit significantly different spatial resolution depending if it was estimated through TTF or MTF. This demonstrates a dependency of the contrast on the resolution due to the non linearity of the different filters and reconstruction algorithms we used.

Furthermore, a significant reduction of both spatial resolution and noise is observed in coronal and sagittal plan compared to axial plan.

Conclusion: The results suggest that CT images acquired in the same conditions but reconstructed in different plans will exhibit differences in spatial resolution as well as in noise power spectra. Those parameters having a direct influence on image quality, this means that lesion detection and characterization by the radiologist is modified. In the end, the visualization of the clinical examinations in different plans has repercussions in diagnostic imaging.

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MONTE CARLO SOFTWARE FOR DOSE CALCULATION IN CT EXAMINATIONS
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Introduction: The significant rise of medical imaging exams in the past few years has led to an increase of collective doses. Despite the numerous tools already available, most of them only provide common dose index (CTDI, PDL) and effective dose rather than absorbed dose to organs. To obtain organ doses, a Monte Carlo (MC) tool, PENEOLOPE-C++, based on the PENEOLOPE simulator developed by Salvat et al is adapted. Our final goal is to develop a predictive tool to obtain the best compromise solution for a CT exam exposure between low organ absorbed doses and high image quality.

Material and methods: Due to the lack of information available in the technical note, the GE VCT Lightspeed 64 tube was modeled using the method proposed by Turner et al. Thanks to HVL and profile measurements, equivalent spectra, inherent filtrations and bowtie filter shapes are obtained. Measurements were then performed in static mode with a CdTe detector associated with an unfolding method developed by the LNHB to achieve experimental spectra and validate the tube model. Ultimately, the axial and helical rotation was implemented in the MC tool. To improve the efficiency of the simulation, two variance reduction techniques were used: a circular and a translational splitting. To validate the calculation, simulated sinograms are compared with the expected ones and the particle distribution along the gantry path is checked. The MC tool and the X-ray tube model were then validated for dosimetric purposes. Measured doses were first obtained in a static mode with a calibrated pencil ionization chamber in a PMMA phantom and compared with simulations. Validations for rotational modes are in progress.

Results: Computed and measured spectra show acceptable discrepancies attributable to a misalignment during measurements. Bowtie filter shapes are in agreement with theoretical expectations. The geometric validations are consistent with the theoretical expectations. Comparisons between measured and simulated integrated doses are good enough, with less than 6% discrepancies for all different acquisition parameters.

Conclusion: The first validations obtained for the use of PENEOLOPE-C++ for CT dose estimations are encouraging. The validation of the rotation motion implementation is part of ongoing research on several phantoms and for several examination procedures in CT exams.

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DEVELOPMENT OF SOFTWARE HELPING IN OPTIMIZING COMPUTED TOMOGRAPHY PROTOCOLS: INITIAL RESULTS
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Introduction: A simulation tool was developed to enable the visualization of the effect of CT protocol optimization on Image Quality (IQ) and radiation dose.

Material and methods: A database of reference Computed Tomography (CT) protocols, adapted to Discovery CT 750HD (GE Healthcare, Wisconsin), for the most encountered clinical indications in CT was established by collecting reference protocols from the American Association of Physicists in Medicine (AAPM) and from optimized and clinically validated protocols in multicentric radiological departments. By adjusting the tube current modulation, three different IQ protocols (low dose, standard, high quality) were defined, for each reference protocol. For these, CT images were acquired on an anthropomorphic phantom (PBU-60®), KYOTO KAGAKU) using the three derived IQ protocols. A software, named ProtoEnhance, was developed to help to optimize CT protocols by displaying the anthropomorphic images and associated volume Computed Tomography Dose Index (CTDIvol). We compared our clinically used hepatic helical acquisition without contrast medium to the standard optimization proposed in ProtoEnhance, qualitatively validated by a senior radiologist, by determining the CTDIvol, by measuring the Signal-Noise Ratio (SNR) in liver and the Contrast-Noise Ratio (CNR) between liver and spleen both on the anthropomorphic phantom and on patient of similar body mass index.

Results: We observed significant dose reductions with the optimized protocol versus our routine protocol on the PBU-60 phantom (CTDIvol = 5.1 mGy vs 6.9 mGy), and on patient (CTDIvol = 5.2 mGy vs 6.6 mGy). SNR and CNR of anthropomorphic phantom images were similar to those of patient images.

Conclusion: ProtoEnhance can help medical staff to optimize CT protocols according to IQ preferences.

Keywords: Computed tomography, Optimization, Simulation

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DEVELOPMENT OF AN ANALYTICAL PEAK SKIN DOSE CALCULATION TOOL IN INTERVENTIONAL RADIOLOGY
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Introduction: In interventional radiology, according to international recommendations, patient follow-up should be adjusted depending on the
Methods and materials: A mathematical correlation have been developed for cardiology between the incidence angle (left-right) of the C-arm and a mathematical representation of the patient skin, assuming that sequences for cardiology between the incidence angle (left-right) of the C-arm and a mathematical model for neuroradiology.

Results: Peak skin doses were respectively 4638 mGy and 235 mGy for patient 1 and for patient 2, using our method compared to 4352 mGy and 515 mGy using the RAD-IR correlation.

Conclusions: We had similar order of magnitude and our method was able to compute dose maps whatever the value of accumulated air kerma. Future improvements will take into account table motion and adapted mathematical model for neuroradiology.

Reference

http://dx.doi.org/10.1016/j.ejmp.2014.10.018

METHOD FOR OPTIMIZING PATIENT DOSES IN INTERVENTIONAL RADIOLOGY: APPLICATION TO HEPATIC ANGIOGRAPHY
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Introduction: This work concerned angiography for radio-embolization of hepatic carcinoma. We present the methodology used to optimize the dose received by the patient.

Material and methods: The imaging system used is a C-arm (Artis Zee Siemens) angiography system. The optimization focus on the setting of the automatic machine such as the dose per image and additional beam filtration or the use of the anti-scatter grid. The phantom TOR18FG associated ARTISCAN software (Aquilab) was used to quantify the 2D image quality. An intervention procedure was performed in collaboration with the medical team. The doses received by the patient were measured by radiochromic film XR-RV3/Ashland and compared with doses given as an indication by the system. A Local Level Reference Dose (LLRD) on the KAP has been determined and a calculation of the expected KAP according to body mass index (BMI) of the patient has been integrated.

Results: The dose per image was decreased from 1.2 μGy to 0.36 μGy resulting in an increase of the spatial resolution of 6.4% and a decrease of 48% of the KAP. The additional filtration of copper increased from 0 to 2.2 mm to reduce by 50% the KAP. Removal of the grid has been validated for patients permitting thin KAP decrease of 42%. The maximum measured by radiochromic film skin dose is 37 mGy to 989 mGy (mean = 253 mGy). The LLRD established for this procedure was set at 45 Gy/cm. KAP expected a priori for example 10 Gy/cm and 50 Gy/cm for patients with a BMI of 18 and 42 respectively.

Conclusions: For hepatic arteriography, a decrease of 75% about KAP between 2011 and 2013 was obtained. We set a NEL 45 Gy/cm compared to 400 Gy/cm U.S. NRD. The establishment of procedures and monitored over time dose values is essential to avoid shifts both material and human.

Keywords: Interventional radiology, Optimization, Patient dosimetry

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LOW-DOSE BIPLANAR RADIOGRAPHY CAN BE USED IN CHILDREN TO ACCURATELY ASSESS FEMORAL AND TIBIAL TORSION WHILE GREATLY DECREASING IRRADIATION
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Aims and objectives: To evaluate in children the agreement between femoral and tibial torsion measurements obtained with low-dose biplanar radiography and CTscan. To study dose reduction ratio between these two techniques both in vitro and in vivo.

Materials and methods: Thirty children with lower limb torsional abnormalities, mean age 14 years, were included in a prospective study. For each patient, biplanar radiographs (EOS imaging system) and CT scan were performed for measurements of femoral and tibial torsion. Values were compared using Bland-Altman plots. Correlation analysis was used to evaluate the relationship between the CT scan- biplanar radiographs difference and the age or the degree of deformity. Intraclass correlation coefficients evaluated interreader agreement. Comparative dosimetric study was performed in vitro using an ionisation chamber in a tissue-equivalent phantom, and in vivo using thermoluminescent dosimeters in 5 patients.

Results: Average differences between CT scan and biplanar radiographs measurements were -0.1 ± 1.11 for femoral torsion and -0.7 ± 1.4 for tibial torsion. There was no correlation between the CT scan-biplanar radiographs difference and the age or the degree of deformity. Biplanar radiographs measurement interreader agreement was very good for both FT (0.80) and TT (0.84). Ratio between CT scan dose and biplanar radiographs dose was 22 in vitro (absorbed dose) and 32 in vivo (skin dose).

Conclusion: Lower limb torsion measurements obtained with biplanar radiographs are comparable with CT scan measurements in children and adolescents with a considerable radiation dose reduction.

Keywords: Child, 3D models, Low-dose biplanar radiography, Femoral torsion, Tibial torsion, Lower limb torsion

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POSTERS

P.04
RADIATION EXPOSURE MONITORING IN MEDICAL IMAGING
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Introduction: Medical patient radiation exposure is a popular and controversial topic, it is the primary source of artificial exposure of the population in industrialized countries. However, the radiation protection of persons exposed for medical purposes is of relatively recent concern (EURATOM 84/466 & 97/42, and recently 2013/59 which repealed the earlier directives).

Materials and methods: The concept of regulatory dose limit is inappropriate in the context of medical examinations. For medical radiation exposures the dose to the patient should be as low as reasonably achievable (ALARA principle) and this can be achieved through the justification and optimization of the radiological examination. Dose should be as low as reasonably achievable but consistent with an image quality allowing a correct medical diagnosis, as a result, the tracking of patient radiation dose is very important and very useful. It should also be noted that many regulations and guidelines express the need for facilities to monitor radiation dose estimations during medical examinations using radiation. Different hospital sites of the Grand Duchy of Luxembourg have opted for a DACS (Dose Archiving and Communication System) solution. DACS uses dose information stored together with the clinical images in the PACS (Picture Archive and Communications Software) in the form of dedicated and sometimes private DICOM header values, printed as an image in SC (Secondary Capture) images, as SR objects (Structured Reports) or in log files stored on the console of the X-Ray device. DACS allows to: (i) view the dose received for a certain exam or hospital stay, (ii) view the patients cumulative dose history (patient dosimetric history), this will implement the principle of justification and answer the following question: in light of this history, is the examination justified?, (iii) determine if a given patient dose exceeds the DRL (Diagnostic Reference Level) established for the given examination or whether the patient required a supplementary
examination, (iv) send Dose information (anonymized) to registries for follow up at population level (i.e. DRL following Euratom), (v) compare 'dose profiles' with other sites/regions, with local policy targets or with standards of practice and (vi) compute the population 'dose profile' for a certain hospital, region or pathology.

Results: In this presentation we will show the potential that a DACS can offer with examples of dose optimisation conventional radiology and mammography conducted at our hospital sites.

Conclusion: DACS is a smart tool, it can automatically collect and monitor dosimetry patient data. It can help the medical physicist to optimize examination protocol.

Keywords: Radiation exposure; ALARA; DACS

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P-05.
SET-UP OF QUALITY ASSURANCE PROCEDURES FOR A 3T-MRI FACILITY STARTING WITH THE AAPM REPORT NO.100
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Introduction: Ultrahigh magnetic fields (more than 3T) are more and more installed in imaging departments in France. Machine Acceptance and time-constancy have to be checked more often than for CT-scan because the contrast of MRI images depends on the sequence and the good functionality of the hardware. Furthermore, it is well known that 3T MRIs are quite sensitive to distortions and eddy current effects. The AAPM report n100 gives good quality assurance guidelines to start from.

Material and methods: A Magphan phantom was chosen to set up a weekly quality control. It will be used to check the image quality parameters by running relevant MRI sequences. The phantom is filled with oil in order to avoid dielectric effects due to water ions in a 3T-magnetic field. The phantom insert are filled with different liquids in order to provide contrast differences in images when performing T1or T2 sequences.

Results: The data are processed using an in-house developed MATLAB program. The results regarding Image quality parameters like homogeneity, SNR, contrast and slice thickness will be presented. Some key concepts about controlling the new complicated functional imaging sequences will be given.

Conclusion: The controlled MRI facility shows a good time-constancy of the contrast and quite no distortion when classical sequences are performed; static field homogeneity and applied gradients including the shim gradients are well performed. Otherwise, the oil-saturation is not always reproducible when performing this sequence. As expected, inversion-recovery sequences will be preferred for better saturation. More complicated sequences as steady state free precession sequences can also be controlled. In this case, tissue contrast is strongly dependent on the repetition time.

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P-06.
IMPLEMENTATION OF AN INNOVATIVE MANAGEMENT STRATEGY OF DOSE AND GOOD PRACTICES IN COMPUTED TOMOGRAPHY
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Introduction: Our objective was to report the impact of the implementation within an imaging department of a team dedicated to dose and image quality in computed tomography (CT).

Materials and method: A CT dose management team ("Dose Team", DT) was established by gathering referent senior radiologists, a medical physicist, dedicated technologists and application engineers. A dose monitoring solution (DoseWatch®, GE Healthcare, France) was concomitantly used within the department. The DT set up a study description designed to specifically tailor each clinical practice, using the following nomenclature "Explored area: Clinical indication: Acquisition technique (optional)". In addition, a dose alert threshold, based on the Body Mass Index (BMI) of the patient and the clinical practice of the Radiology department was established for each study description in compliance with national dose reference levels. For 45 examinations of standard BMI patients (18.5≤BMI≤25), with the study description "Thorax-Abdomen-Pelvis (TAP): Hematology", the Dose-Length Product (DLP) was noted, the corresponding effective dose and the number of examinations with a dose above dose alert threshold was estimated. The same approach was used for the study description "TAP: Oncology : Multiphase" with a cohort of 42 patients of the same BMI category as above.

Results: For the study description "TAP: Hematology" the mean DLP was 784 ± 360 mGy.cm corresponding to an effective dose of 12 ± 5 mSv. 2 examinations, representing 4% of the total, were above the dose alert threshold. For the study description "TAP: Oncology: Multiphase" the mean DLP was 1,472 ± 861 mGy.cm corresponding to an effective dose of 22 ± 13 mSv. 5 examinations, representing 12% of the total, were above the dose alert threshold.

Conclusion: The implementation of the DT has enabled the development of a novel examination description within a dose management solution, tailoring dedicated clinical indications. This process enabled a strict follow-up of current recommendations provided by the American Association of Physicists in Medicine (AAPM) for the management of CT acquisition protocols.

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P-07.
OPTIMISATION OF CT SCAN ACQUISITION PROTOCOL WITH ITERATIVE RECONSTRUCTION
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Objectives: Find the optimal scanner and iterative reconstruction method parameters to keep the same image quality as standard filtered back projection (FBP) reconstruction at lower doses in computed tomography (CT).

Methods: A two-step method (objective and subjective quality) was set up to maintain constant quality while using two iterative reconstructions (ASIR, SAFIRE) on two MDCT scan (CT 750 HD Discovery, General Electric Healthcare Corp, Milwaukee USA and SOMATOM Flash Dual Source CT; Siemens). The first is to produce Catphan 600 images at different dose levels (using different tube currents and potentials), with all ASIR and SAFIRE settings. The assessments for image quality are the signal to noise ratio (SNR), high and low resolution contrast (HRC, LRC). These criteria are systematically measured on the images, and compared to those on FBP with standard dose. This comparison leads to selecting for each dose the iterative setting that gave the most similar image. For additional information, the noise power spectrum (NPS) is also calculated. This criterion is not a selective one but could be a link between metrics and subjective criteria. The second step will be to produce anthropomorphic phantom images using selected protocols for subjective notation. The Radiologist will evaluate the images for different criteria such as overall quality image, noise level, sharpness.

Results: According to the literature, the use of iterative reconstruction algorithms leads to a noise reduction into images; this effect is increasing with the iteration level used. The maximum abscess of the NPS curve should be shifted into low frequency and the ordinate will be lower as the level of iteration increased. In terms of subjective image quality, the literature report that the images produced with a high iteration level have a lower score on radiologist evaluations.

Conclusion: According to the literature, the final dose reduction percentage for a given image quality should be between 20% and 60 %.
imprecision in this prevision is due to the differences between standard protocols in studies read. The Optimal iteration level should be between 20% and 60% for ASIR and level S3 for SAFIRE.

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P-08. DEVELOPMENT OF A PREDICTIVE MODEL TO REDUCE THE PATIENT RADIATION DOSE RISK IN INTERVENTIONAL CARDIOLOGY

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Introduction: This study aims at identifying the high-dose procedures in a cardiology department and finding correlation factors to predict the risk of deterministic effect occurrence.

Materials and methods: A working group composed of medical physicists, interventional cardiologists and Radiation Safety Officer was created. DOSITRACE platform, allowing automated data collection and historical patient dosimetry was installed and a risk management approach based on a curative-based perspective has been implemented. It includes the integration of dose thresholds and medical follow-up in case of overtake. The use of DOSITRACE in clinical routine has enabled to identify the recalncalization of Chronic Total Occlusion (CTO) as the one which may deliver the highest patient radiation dose. Subsequently, a radiochromic film dosimetry was implemented for 103 CTO procedures to measure precisely the maximum skin dose delivered to the patient (Peak Skin Dose PSD) which is the only indicator of deterministic effect occurrence risk. The working group has become interested to figure-out the factors that determine the escalation of the radiation dose delivered to the patient. It studied correlations between PSD and some medical indicators.

Results: The mean ± standard deviation for measured PSD of 103 patients were: 2.9 ± 2 Gy. A correlation between the PSD and the pair patient diameter]/-CTO Score was found. A predictive model of PSD based on a linear regression and including these two factors was developed. The results for PSD estimation using this model are as follows:

- Considering the most common artery (right coronary) and PSD lower than 6 Gy, the deviation was: 0.85 ± 0.55 Gy.
- Considering all patients, the deviation was: 1.3 ± 0.9 Gy.

In parallel, a method which provides estimates of the biologically adjusted dose for sessions occurring at least 24 hours apart was implemented in DOSITRACE.

Conclusion: This project has enabled to identify the high-dose procedures and to implement a model to predict the risk of deterministic effects occurring, both based on the patient diameter and the J-CTO Score and including cumulative dose.

Keywords: Deterministic effect, Interventional Cardiology, PSD

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P-09. A NEW SCINTILLATING FIBER DOSIMETER FOR REAL-TIME MEASUREMENT IN RADIOLOGY AND RADIOTHERAPY

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Introduction: We present an innovative dosimetric system, based on an optical fiber technology, dedicated to the quality control and the real-time dose measurement in the fields of radiotherapy and radiology.

Materials and methods: The measurement device is composed of a radio-transparent plastic optic fiber (POF) based probe and a dedicated photometer. The light measurement process is based on a temporal coincidence measurement method and is patented. A set of measurements was performed on a GE Optima scanner using a 10cm in length probe in comparison with a pencil chamber provided by PTW (CT chamber type 30009). We studied the response of the dosimeters, with several collimations apertures, in both medium : air and a water-like phantom of 16 cm. Another set of data were acquired, in the frame of the TRS 386 protocol in radiotherapy, using a 1mm in length POF probe in comparison with a PTW ionization chamber (Semilabs Chamber Type 31010). Different dose and dose rate were studied.

Results: In TDM, the response of the ionization chamber, in regard of the collimation aperture, is not linear from 10mm aperture whereas the POF based dosimeter exhibit linear results. In radiotherapy, the measurements lead under a 10 x 10cm² field of exposure exhibit a good correlation among the two detectors.

Conclusion: This set of data has validated the good behavior of our dosimeter in both area of radiodiagnostic and radiotherapy. We are currently developing new probes of specific length, especially 30cm, dedicated to large aperture TDM, specific diameter (0.25mm) in order to perform live and in vivo measurements during interventional radiology procedures and Endoluminal probes dedicated to brachytherapy. These probes will also be tested in several clinical centers.

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P-10. A NEW INDICATOR FOR THE EVALUATION OF DOSIMETRIC PRACTICES IN INTERVENTIONAL RADIOLOGY

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Introduction: The evaluation of dosimetric practices in interventional radiology (IR) is based on inappropriate indicators arising from the variability in procedures. It is interesting to study the dose-area product per image (DAPPI) as an indicator to determine the reference level (RL) in IR.

Materials and methods: 3100 data were collected by 5 interventional cardiology services. The DAPPI has been correlated to BMI and the dependent characteristic of the in situ procedures. Four statistical methods were compared to set the reference level (RL) for the third-quarters.: morphologic normalization (Miller 2009), by BMI range, all BMI confounded and a method based on outliers. This last consists, firstly, the elimination of extreme values by “outliers method” to increase the robustness of the distribution statistics. In addition, it involves the discrimination of the set of points below the median of the population. From the remaining sample, setting a second median provides the 75th percentile. Two approaches of DAPPI are studied from total DAP (DAPPI total) and the other from the graphy DAP (DAPPI graphy) only.

Results: Three statistical methods give similar results in coronary angiography for DAPPI graphy: the RL with “range method” gives a 49.29 mGy.cm²/image (23 < BMI <25), 48.9 with the “Miller method”, 50.98 with the “Outliers method”. With the fourth method, “all BMI”, the RL is 58.45 mGy.cm²/image.

For DAPPI total, the RL is 99.57 with “outliers method” while we obtain 84.98 by the “range method”, 83.42 with “Miller method", 105.49 with the “all BMI”.

Conclusion: The correlation of DAPPI with BMI seems to be more relevant indicator in the evaluation of practices in interventional cardiology because it overcomes the variability in fluoroscopy time, morphology and clinical indications. Furthermore, dose thresholds establishment method will be based on RL set up. DAPPI applied to interventional neuroradiology and peripheral vascular are still under construction.

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P-11. DEVELOPMENT AND VALIDATION OF AN INTERACTIVE DOSE CALCULATION PLATFORM IN INTERVENTIONAL RADIOLOGY

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Introduction: This study presents the development of em.SIM, an interactive platform dedicated to patient and worker radioprotection in interventional radiology, in a virtual reality environment.

Materials and methods: Procedures parameters such as patient or worker position, or C-arm control are transferred to a calculation module based on the Monte Carlo code PENELOPE, which handles particle transport. em.SIM mimicks the actual interventional scene and calculate peak skin doses, dose maps and organ doses. We validate the tool in an anthropomorphic phantom, by comparing em.SIM calculation and measurement (based on Optically Stimulated Light dosimeters) in a coronaryography setting. Ongoing development will allow to calculate interactively the dose in any point in the room in few seconds in order to optimize staff protection.

Results: Calculated and measured peak skin doses agreed within 3.5%. The largest discrepancy between the simulated dose map and the estimated dose from the dosimetric report was 20%.

Conclusion: Results confirm that of em.SIM is well adapted to evaluate radiological risk, optimize interventional procedures and train staff. Clinical validations are currently ongoing. By incorporating staff radiation protection data, em.SIM will offer a full range of information to minimize radiation risk in interventional radiology.

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P-13.

INFLUENCE OF A CONNECTED BUT INACTIVE COIL ON A MR EXAM: THE LIVER IRON CONCENTRATION MEASUREMENT

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Context: In MRI-based studies of hemochromatosis, liver iron concentration (LIC) can be measured using images acquired with the main RF transceiver also known as the body coil. However, the surface coil, normally used for a liver MRI exam remains connected while being inactive for the LIC-measurement acquisition. This torso coil may generate inhomogeneity which may alter the diagnosis.

Purpose: In this work, we assess the influence of the torso coil on the LIC measurement and image quality.

Material and methods: Twelve healthy volunteers were included in the study which was carried on a 1.5T GE MR scanner. First, the images were acquired using the body coil with the torso coil connected (mode 1). Then, the acquisitions were performed with the body coil only (mode 2). For the measurement of the LIC, two techniques were used: a first one based on a gradient echo sequence and the second based on a breath-held multi-echo gradient echo sequence. The liver-tomuscle signal intensity ration (L/M), which is known to be correlated with the LIC, was also calculated. In addition, we calculated the contrast and contrast-to-noise ratio between liver and muscle. For the statistics, a Student’s t-test was performed in order to point out significant differences between the two acquisition modes.

Results: The outcomes show a slight decrease in the investigated parameters when the torso coil is not connected. The Student’s t-test indicate that the fall-off is not significant (t=0.07, p-value=0.94).

Conclusion: We succeeded to establish that the connected torso coil does not influence the LIC measurement in MRI. In a purpose of quality assurance, similar approaches may be adopted if the use of a device might be suspected to influence clinical MRI exam.

References


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P-14.

CHARACTERIZATION OF MR IMAGES GEOMETRIC DISTORTIONS: DESCRIPTION AND VALIDATION OF A METHODOLOGY

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Purpose: To describe a method for characterizing MR images geometric distortions in the context of 3D acquisition.

Methodology: Our methodology is based on the use of phantom containing known-coordinate control points which are arranged in a volumic configuration. These known coordinates are provided by the computer-aided design, thus representing for the ground truth. Then, image-based coordinates are calculated using the phantom’s acquisitions. Distortions are evaluated as the difference between the image-based coordinates and the true coordinate of the phantom. The operations enabling to extract the image-based coordinates were programmed in MATLAB. They include image processing techniques such as segmentation, feature extraction and non-rigid registration.

Validation: The method was validated using numerical simulation: a varying-amplitude deformation field [2 mm to 18 mm] was applied to a 14 x 14 x 14 mm3 volume which contains control points. The analysis program was applied to the distorted data. The accuracy of the algorithms was evaluated by comparing the measured distortions to the applied ones. The algorithm’s precision was assessed by calculating the coefficient of variation of measurements performed for different amplitudes of deformations.

References


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Results: The outcomes indicate that the algorithms enable to measure the images' geometric deformations with an accuracy higher than 98% and a precision superior to 99%.

Discussion – perspectives: The proposed method enables a straightforward, accurate and precise characterization of geometric deformations. This is an advantage over several techniques which are available in the literature. Besides, such method of characterization is a first step toward the correction of geometric distortions in clinical images which can be used for planning radiotherapy and curie-therapy procedures. Additional work have been ignited in order to design and build a control-point phantom and thus implementing the whole methodology.

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P.15.
MRI FUNCTIONAL SEQUENCES APPLIED TO RADIOTHERAPY TARGET CONTOURING
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MRI has been entering a revolution for the last five years by giving better spatial resolution, reducing acquisition time and providing a lot of new acquisition sequences. Furthermore, MRI is mostly used in neuroradiology. So many sequences improvements and developments are performed for brain functional understanding and diagnosis. But radiotherapy targeting can benefit from these new functional sequences applied to extra-cranial regions. The sequences like diffusion and T1-perfusion can be performed outside the skull because they are quick enough to avoid artifacts due to organs movements. For example, quantitative parameters of T1 perfusion are often unexploited in ante and post-radiotherapy treatment although the movements. For example, quantitative parameters of T1 perfusion are often unexploited in ante and post-radiotherapy treatment although the movements. 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THURSDAY 5 JUNE

SESSION: QUALITY CONTROL IN RADIOTHERAPY

ORAL COMMUNICATIONS

VALIDATION PROTOCOL OF A DETECTOR FOR QUALITY CONTROL OF TREATMENT PLANS IN RADIOTHERAPY: APPLICATION TO OCTAVIUS4D/PTW
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Introduction: For static or rotational IMRT, the use of a new device for quality control of treatment plans has to be validated. We expose the used method to integrate Octavius4D that is the new PTW device.

Materials and method: The proposed protocol of validation consists of two steps. The first step is to check the consistency between dosimetric and mechanical characteristics of detector and its clinical use. The second step is to evaluate the detector capacity for error detection. By simulating known errors on treatment plans on leaves, gantry, collimator and dose.

Octavius4D is composed of an ionisation chambers matrix, an acrylic phantom with a rotation unit and a software (VeriSoft 5.1).

Results: Dose response of Octavius 4D was linear (R²=1) from 1 to 400 UM. A standard deviation of 0.54% was obtained for measurement performed with dose rate range varying from 25 to 400 UM/min (10 measurements). For gantry speeds of 0.65 /s and 3.89 /s, the range of deviation between Octavius4D values than linac gantry values was 0.5° and 4.2°. For VMAT plan, Octavius 4D reproducibility verification was 0.37. Percentage of allowed points with gamma index test decreased 15% and 57% for leaf bank errors of 2mm and 5mm respectively regarding to results with original plans. This percentage decreased 15% and 29% for gantry errors of 2° and 5° respectively; it decreased of 11% and 43% for dose errors of 2% and 5%. Errors of rotation collimator were not detected.

Conclusion: The validation protocol of Octavius4D allowed us to check compatibility of its characteristics with control of VMAT treatment plans and then to quantify Octavius4D capacity for error detection. This work is necessary to maintain a critical analysis of results obtained with sophisticated detectors in order to limit a black box effect that can be dangerous.

Keywords: IMRT/VMAT, Quality control, Detector

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ACCURACY OF DOSE CALCULATION ALGORITHMS IN MULTIPLAN TREATMENT PLANNING SYSTEM IN PRESENCE OF HETEROGENEITIES
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Purpose: Advanced stereotactic radiotherapy (SRT) treatments require accurate dose calculation for treatment planning especially for treatment sites involving heterogeneous patient anatomy. The purpose of this study was to evaluate the accuracy of dose calculation algorithms, Ray tracing and Monte Carlo (MC), implemented in the MultiPlan treatment planning system (TPS) in presence of heterogeneities.

Methods: First, the LINAC of a CyberKnife radiotherapy facility was modeled with the PENELOE MC code. A protocol for the measurement of dose distributions with EBRT films was established and validated thanks to comparison between experimental dose distributions and calculated dose distributions obtained with MultiPlan Ray tracing and MC algorithms as well as with the PENELOE MC model for treatments planned with the homogenous Easy cube phantom. Finally, bones and lungs inserts were used to set up a heterogeneous Easy cube phantom. Treatment plans with the 10, 7.5 or the 5 mm field sizes were generated in Multiplan TPS with different tumor localizations (in the lung and at the lung/bone/ soft tissue interface). Experimental dose distributions were compared to the PENELOE MC and Multiplan calculations using the gamma index method.

Results: Regarding the experiment in the homogenous phantom, 100% of the points passed for the 3%/3mm tolerance criteria. These criteria include the global error of the method (CT-scan resolution, EBRT dosimetry, LINAC positioning ...), and were used afterwards to estimate the accuracy of the MultiPlan algorithms in heterogeneous media. Comparison of the dose distributions obtained in the heterogeneous phantom is in progress.

Conclusion: This work has led to the development of numerical and experimental dosimetric tools for small beam dosimetry. Raytracing and MC algorithms implemented in MultiPlan TPS were evaluated in heterogeneous media.

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A SEMI-EMPIRICAL MODEL OF IN-FIELD AND OUT-OF-FIELD BREMSSTRAHLUNG DOSE DISTRIBUTION IN HIGH ENERGY ELECTRON BEAMS USED IN EXTERNAL RADIOTHERAPY

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Introduction: A better understanding of the dose distribution effects in normal tissues becomes essential to know how best to exploit modern technologies in radiotherapy. Bremsstrahlung dose component became essentially from applicator’s scrapers, while out-of-field bremsstrahlung dose. Our modelling approach can be used to provide good representation of bremsstrahlung dose distributions in all healthy tissues for any applicator size and type and for any electron beam energy used in high-energy electron beam therapy. The calculating time is relatively short. To take account total peripheral dose out-of-field, an additional model is under developing to estimate out-of-field scattered electrons dose component.

Keywords: Electron beam, Therapy, Out-of-field dose, Bremsstrahlung component

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POSTERS

P-16. CORRELATION BETWEEN THE GAMMA INDEX OF A VMAT PATIENT QUALITY CONTROL AND A MODULATION INDEX CALCULATED FROM RT PLANS

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Introduction: The IMRT or VMAT Patient quality controls are successful when the gamma index is higher than 95%. A lower result drives to a notification but the treatment is generally performed as calculated due to the lack of guiding lines to improve the dosimetry. We propose in this study to look for a correlation between the gamma index and the geometrical and dosimetrical characteristics of the RT Plans.

Materials and methods: The archtherapy plans (RapidArc, Varian) are studied in one hand with the portal imaging system aSi000 and the Portal-Dosimetry module (3%, 3mm, threshold 30%, local and global), and on the other hand with the cylindrical phantom Sun Nuclear ArcCheck. The plans are also analyzed on Matlab to be reduced to an unique modulation value which depends on the MLC geometry, the leaf speed and the delivered dose for each control point.

Preliminary results: We have for the moment highlighted that lower gamma indexes are related to plans which present a speed histogram with an elevated contribution of highest speeds.

Conclusion: A more complete correlation study, which is under progress, is focused to the dosimetric planification optimisation in order to obtain a better gamma index.

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P-17. CHARACTERIZATION AND CORRECTION OF THE ANGULAR DEPENDENCE OF 2D CHAMBER ARRAY MATRIXX IBA WITHIN THE FRAMEWORK OF TOMOTHERAPY

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Introduction: In our institution most patients are treated with intensity modulated arctherapy techniques. A patient delivery quality assurance plan (DQA) is performed prior to every treatment. In the case of Tomotherapy, a 2D array of ionization chambers (Matrixx from IBA) is used. The array’s angular dependence response is already known and provided by IBA. However, the constructor’s method is not applicable in the case of tomotherapy because the inclinometer cannot be used on these machines. The objective of this work is to characterize the intrinsic angular dependence of the array and to develop a computing tool to account for it within the framework of Tomotherapy V5 Operating System (OS).

Materials and methods: To carry out this project a MultiCube phantom with Omnipro I’Mrt software, a set of Gafchromic EBT3 dosimetry films, Epson Scan 10000XL, a language editor and Matlab software were used. To determine the correction factors, a set of 26 beam incidences were delivered and measured with the array. The same process was repeated with Gafchromic films. The phantom allows _Im placement at the same effective measurement depth as the ionization chambers. The two measured data-sets were compared using Omnipro I’Mrt and Matlab software. Correction factors were calculated as the ratio of the array and _Im measured dose.

Results: For some angles, we observed that the angular correction factor provided by the constructor is underestimated of around 1%. Furthermore, we have observed a difference between central and peripheral angular correction factors i.e. for 45°, correction factors of 1.021 at the center and 0.910 peripheral were determined.

Conclusion: We have succeeded to obtain a map of angular correction factors for a limited number of beam angles. Future work in progress is to extend it to all angles by applying this methodology to a full discrete sample set.

Keywords: MatrixXX, Angular dependence, Gafchromic films, DQA

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P-18. A SINGLE EBT3 GAFCHROMIC CALIBRATION CURVE FOR DOSE MEASUREMENT FROM 0 TO 8.5 Gy/FRACTION

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Introduction: The use of gafchromic films is nowadays essential in radiotherapy. EBT3, which have succeeded to EBT and EBT2, are the subject
from 6x6cm

Thermoluminescent dosimeter TLD-700 powders were used. Measurement of peripheral dose was measured in a water phantom as a function of off-axis distance from 5cm to 65cm from the field edge for SSD=100cm. Thermoluminescent dosimeter TLD-700 powder was used. Measurements were taken at both depths of 1cm and 10cm, using applicator sizes from 6x6cm² to 20x20cm², the results assuming that signal of TLD is proportional to dose.

Results: Whatever the field size, a peak dose spot appears at 15cm from the field edge for Siemens applicators. For Siemens Primus with an applicator size of 10x10cm², this peak reaches to 2.1%, 1%, 0.9% and 1.3% of Dmax for 6, 9, 12 and 18MeV electron beams, which was doubled for 6x6cm² field size. For Siemens Oncor, the above applicator size, this peak dose was 0.8%, 1.2% and 1.3% of Dmax for 6, 9 and 12MeV respectively, which was doubled for 20x20cm². In contrast for Varian 2300C/D, the dose at 15cm from field edge were 0.3%, 0.6% and 1.1% of Dmax for 6, 12 and 18MeV respectively. No peak dose spot was evidenced for Varian applicator.

The measured doses at depth of 10cm were 2-3 times lower than doses at depth of 1cm for out-of-field distances from 5cm to 35cm, and were 4-7 times lower for larger distances.

Discussion/conclusion: This work analyzed peripheral dose for different electrons beams energies and three different applicator types. It was evidenced that depending on beam energy, applicator size and type, peak dose at 15cm from field edge ranges from 0.3% - 2.7% of the Dmax. Measurements made at 10cm depth showed that, depending on beam energy and applicator size and collimator size, the dose at 15cm from field edge is 0.07-0.2% of Dmax.

Although, the debate on signal to dose conversion coefficients for mixed fields is still ongoing, our results should be considered because, to date, peripheral dose from electrons beams are not fully accounted for by TPS.

Keywords: Peripheral dose; Electron applicator; Electrons beam therapy

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SESSION: NUCLEAR MEDICINE

INVITED COMMUNICATION

GENERAL OVERVIEW OF THE NEW CAMERAS DEDICATED TO MYOCARDIAL PERFUSION IN SPECT

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Introduction: Myocardial single-photon emission computed tomography (SPECT) is considered as a reference technique for the detection of coronary artery disease and for stratifying the risk of coronary artery disease patients. Developed in the 1980s with rotating Anger gamma-cameras, this technique had up to recently many disadvantages such as a low spatial resolution and a low image quality, and the need of long acquisition times and of high injected activities.

Material & methods: Recently, this technique has been markedly enhanced by a generation of new imaging systems, working with semiconductor Cadmium Zinc Telluride (CZT) detectors. Two CZT cameras, dedicated to nuclear cardiology have been recently commercialized: the Discovery NM-530c (General Electric) and the DSPECT (Spectrum Dynamics). Contrary to Anger gamma-cameras, these CZT cameras use a principle of direct detection of the emitted photons. The interaction of a gamma photon with the semiconductor material produces a number of pairs of electron-hole and this number is proportional to the deposited energy. The performances of these cameras have been already comprehensively analyzed on phantoms, as well as on human SPECT images, when using routine recording and reconstruction SPECT parameters.

Results: The results show a dramatic superiority of the CZT cameras in terms of detection sensitivity, spatial resolution and contrast-to-noise ratio, compared to conventional Anger cameras. These properties allow both acquisition times and injected activities to be markedly reduced. In our department a very low-dose protocol has been elaborated for stress-SPECT with ⁹⁹mTc-Sestamibi. Mean effective dose for patients is only 3,6 mSv, whereas values > 14 mSv are currently reached with conventional protocols on Anger cameras. In addition, mean acquisition times for stress and rest acquisition are, respectively, 7 and 3 minutes, corresponding to a decrease by a factor 2 compared with current protocols from Anger cameras.

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Conclusion: Finally, the good energy resolution of the semiconductor detectors allows the simultaneous recording of two different isotopes, such as for the dual-isotopes protocols where $^{201}$TI is injected at rest and $^{99m}$Tc-Seastamibi at stress.

**Keywords:** Myocardial SPECT, CZT cameras, Performances

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**ORAL COMMUNICATIONS**

**IMPLEMENTATION AND VALIDATION OF THE «COLLAPSED CONE» SUPERPOSITION PRINCIPLE IN INTERNAL DOSIMETRY FOR YTTRIUM 90 THERAPY**

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**Introduction:** A collapsed cone (CC) superposition method has been implemented within our dosimetry platform VoxelDose for 90Y therapy as an alternative to Monte Carlo (MC) simulations.

**Methods:** Our CC implementation uses a dose point kernel computed in water for 90Y using the MCNP MC code. This kernel is scaled according to the radiological distance between source and target voxels in order to account for tissue heterogeneities. The validation was performed against MCNP using semi-infinite sources corresponding to the 6 interface combinations including soft-tissue, lung and bone. The comparisons to MC have been performed in terms of relative absorbed dose difference ($\Delta$DAD) in low gradient regions (LGR), distance to agreement (DTA) in high gradient regions (HGR) and the combined $\gamma$ criterion with a tolerance of 1% in dose and 1 mm in distance. An additional validation has been performed for 2 clinical cases, corresponding to simulations of an intravascular liver treatment with a lung shunt (case 1) and a bone metastasis treatment in a lumbar vertebra (case 2). Both cases were compared to MCNP in terms of DVHs and average AD to organs (AD).

**Results:** For the semi-infinite sources, $\Delta$DAD in LGR was below 1.0%, DTA in HGR was below 0.6 mm. All profiles passed the $\gamma$ (1,1,1 mm) criterion. For clinical case 1, AD differed by -0.8%, -0.2% and -0.3% in lung, non-tumoral liver and the tumour, respectively. DVHs departed by less than 0.6%, 0.4% and 0.3% for lung, non-tumoral liver and the tumour, respectively. For case 2, AD differed by 0.3% in the vertebra and 0.1% in bone marrow. DVHs departed by less than 0.6% in the vertebra and less than 0.4% in the bone marrow. Calculation times were below 4 minutes on a single processor for CC and 40 hours on a 40 nodes cluster for MC (108 histories).

**Conclusion:** Our results show that the CC absorbed dose computation for 90Y therapy agrees well with MC on heterogeneous media, while greatly reducing computation times. Therefore CC is a promising algorithm for radionuclide dosimetry.

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**DOSITEST: A VIRTUAL INTERCOMPARISON OF CLINICAL DOSIMETRY TRIALS IN NUCLEAR MEDICINE BASED ON MONTE CARLO MODELING**

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**Introduction:** The interest of dosimetry calculations in Nuclear Medicine consists in maximizing absorbed dose in the tumor while minimizing healthy tissues toxicity. However there is no reference, standardized dosimetric protocol to date. DositTest project (www.dositest.com) aims at evaluating the impact of the various steps that contribute to the realization of a dosimetric study, by means of a virtual multicentric intercomparison based on Monte-Carlo modelling. The different steps of the generation of the scintigraphic images constituting the dataset of the comparison, following clinical centre IEO (Istituto Europeo di Oncologia, Milan)’s imaging protocol, will be presented here.

**Material and methods:** The radiopharmaceutical selected for this study is the $^{111}$In-pentetreotide (OctreoScanTM). Pharmacokinetic data from literature are used to define a compartmental model matching its biodistribution and to derive Time-Activity Curves for each functional compartment (liver, spleen, kidneys, blood, bladder, extravascular fluid + 2 tumours) The virtual patient used for this study is based on the whole-body version of the hybrid anthropomorphic model NCAT. Monte-Carlo code GATE v6.2 is used both for IEO’s gamma camera modelling, allowing the final generation of scintigraphic images, and for reference dosimetry calculations directly derived from biodistribution data.

**Results:** Planar and tomographic scintigraphic images were generated at different times after injection, following IEO’s imaging protocol. Computation times for “step and shoot” whole body simulations (5 steps) were considered acceptable on a computing cluster of 480 virtual cores: 10 days for extra-vascular fluids, 28h for blood, 12h for liver, 7h for kidneys, and 1-2h for bladder, spleen and 1-2 cm3 tumors. GateLab was used to reduce computation times by a factor 2. After validation of dosimetry calculations with GATE v6.2, a 3D absorbed dose map was established for this OctreoScanTM study.

**Conclusion:** The hypothesis that it is feasible to model the entire process leading to the generation of a dataset for a dosimetry study has been confirmed. The next step will be to collect IEO’s dosimetry results and to compare them to our reference dosimetry.

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**SESSION: HADRONTHERAPY**

**INVITED COMMUNICATION**

**PARTICLE ACCELERATORS AND BEAM OF PROTONS OR CARBON IONS DEDICATED FOR RADIATION ONCOLOGY**

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**Introduction:** Since the rationale on the potential advantages of heavy charged particles (Wilson, 1946), a back and forth has been enabled between possibilities or limits of particle accelerators and clinical specifications. We will describe some considerations and practical cases of these sixty years of evolution.

**Material and methods:** Technologies required to accelerate electrons in order to achieve “standard” radiation oncology is easily reached due to physics properties of electrons. In the case of heavy charged particles the challenge is much more difficult to obtain a reasonable medical device. Furthermore, the properties of the expected scanning beams are impacted by the different micro and macro time structure due to the several accelerating techniques.

**Results:** After an era (1955-1985) used for first practical experimentations with old nuclear physics machines, the present era (1985-2015) is giving the first results of what can be “industrialized” solutions: mature technologies with a first level of compactness in order to be integrated in an hospital environment, beam properties assuming uncertainties on tissues and organ motion considerations, integration in the global radiation oncology approach in terms of surrounding softwares and know-how of teams.

**Conclusions:** The 3D dynamic beam promised by charged particles is now becoming a reality. The path to become an established field of oncology must take in account the lessons learned during the last thirty years: appropriate level of innovation, reasonable cost of investment and service, integration of the new data of radiation oncology (organ motion, variability of tissues answers, combined approach with biology, level of safety required, complexity of the global process of treatment).

**Keywords:** Particle accelerators, Radiation therapy

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ORAL COMMUNICATIONS

UPDATE OF THE HADRONThERAPY PROGRAMS IN FRANCE
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For the past decade, hadrontherapy (a form of radiotherapy based on heavy particles) which consists in the use of protons (P) and carbon ions (C), has enjoyed considerable developments worldwide: 46 centers are fully operational (incl. 6 for C), 27 under construction, and 11 projected. As a whole, almost 110,000 pts have been managed so far, most (i.e. 85%) using P including a substantial proportion, in Europe: 34,000 pts, from which 1/3 have been reported from France. Since 1991, 2 centers dealing with high (Orsay) or low energy beam (Nice) are developing clinical indications, initially pioneered at the Harvard Cyclotron, in Boston. They represent 6,500 and 5,000 pts or so, respectively. They include: ocular melanomas (approx. 400 new cases/Y), low-grade skull base sarcomas (i.e. chordomas and chondrosarcomas, < 200 cases/Y), and more recently spinal/para spinal sarcomas, nasal/para nasal malignancies (adenoid cystic carcinomas...), and extra axial CNS tumors (meningiomas...). Initiation of Pbased pediatric programs has been one of the major contributions of the French teams, motivated by the considerable potential toxicity of RT in this age-group. Detailed evaluations are being conducted in Orsay, on 300 children affected with CNS tumors, and orbital and “para meningeal” rhabdomyosarcomas. Clinical studies on new tumor-sites currently piloted in adults, abroad (prostate, lung, liver, esophagus, ENT...) are still pending, and might be initiated when modern technologies (esp. beam-scanning) are made available. C programs are highly selected and confined to 2 European centers in Heidelberg, and Pavia. Socio-economic studies have been performed in Lyon, by the ETOILE group and could help design future P= C projects such as ARCHADE, in Caen.

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PROTON THERAPY AND NANOPARTICLES: ASSESSMENT OF POSSIBLE PHYSICAL EFFECTS INVOLVED
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Proton therapy is advantageous with respect to conventional radiotherapy thanks to its selective deposition of dose in depth. However its therapeutic index can be further improved by combining it with nanoparticles (Nps). Porcel and collaborators have shown a significant enhancement of the biological efficiency in fast carbon irradiations in the presence of platinum Nps. These Nps increased by a factor of almost 2 the number of DNA double strand breaks [1]. This effect has been tentatively ascribed to ionisations and excitations of the Nps by the secondary electrons produced in the tracks. The aim of this work is to evaluate this hypothesis and in particular the possible contribution of Auger electrons.

Monte Carlo simulations were performed with GATE (Geant4 Application for Tomographic Emission) platform simulation, version 6.1. In the calculations 200 MeV protons impinged in a water tank insided which a thin layer of either 0.2 mg/mL or 10 mg/mL of Au Nps [2]. The thin layer was placed at the Bragg Peak position. A significant increase of secondary electrons was not observed in the presence of AuNps. The slight augmentation of secondary electrons found is mainly located at very low energies (<250 eV). It should be highlighted that the cross sections of general purpose codes as Geant4 are not extremely accurate. However the absence of a significant increase of the number of secondary electrons produced indicates that physical processes are probably not the main responsible for the enhanced biological damage observed.

Keywords: Nanoparticles, Proton therapy, Monte Carlo

References

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SESSION: STEREOtaxy

ORAL COMMUNICATIONS

SILICON STRIP DETECTOR FOR QUALITY ASSURANCE IN SYNCHROTRON MICROBEAM RADIATION THERAPY
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Introduction: Microbeam Radiation Therapy (MRT) is a novel cancer treatment modality currently under development at a few synchrotron facilities around the world. The principle is to divide the incident synchrotron beam into an array of microbeams using a multislit collimator (MSC) in order to benefit from the dose volume effect which will spare the normal tissue while keeping a detrimental effect on the tumour tissue. The dose delivered within the microbeams is called the peak dose and the dose delivered in the middle of two microbeams, the valley dose. A high peak dose is desirable to deliver a dose to deep seated targets, but the valley dose needs to remain under the normal tissue tolerance level. Thus an optimised Peak to Valley Dose Ratio (PVDR) is needed. Considering the small size of the beams and massive dose rates (up to 15 kGy/s) used in MRT, accurate real-time dosimetry is a major challenge. The Centre for Medical Radiation Physics has thus developed the X-Team quality assurance (QA) system based on a high resolution silicon Single Strip Detector (SSD) and wide dynamic range (105) readout system.

Materials and methods: In-air fluence profiles have been measured with the SSD with the aim to develop a QA technique for MSC alignment. Also, PVDRs have been obtained in both water and solid water phantoms and finally, depth dose curves have been acquired under homogeneous beam configuration in order to be compared with a reference ionisation chamber (IC). Measurements have been carried out at both the European Synchrotron Radiation Facility and the Australian Synchrotron.

Results: The in-air measurements’ results showed a good correlation between the SSD and the monitor ionisation chamber used for MSC alignment purposes. Depth dose curves showed an over-response of the SSD at shallow depths.

Conclusion: The SSD showed its ability to perform qualitative measurement of the microbeams intensity profile and to estimate the PVDRs. Nevertheless, considering the discrepancy observed in comparison with the IC, an investigation of the detector energy dependence is required.

Keywords: Microbeam dosimetry, Silicon, Synchrotron

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A REAL-TIME QUALITY ASSURANCE INSTRUMENTED PHANTOM FOR HDR AND PDR BRACHYTherapy
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Using high dose rate brachytherapy afterloader requires a quality assurance procedure to control positioning and dwell time of radioactive seed, and to verify the delivered dose compared to treatment planning system (TPS) calculation [1]. For this purpose, we have designed, realized and tested an instrumented phantom prototype to perform all of these controls in real time.
The proposed instrumented phantom includes two punctual dosimetric gallium nitride based probes (GaN - sensitive volume 0.6x0.6x1mm³) coupled through optical fibers to a two-channel photodetection module. The module is basically composed of two silicon photomultipliers synchronized together by a FPGA card. The two probes are positioned in a PMMA cylinder, at 18 mm away from its axis and spaced apart by 29 mm. A 2 mm diameter source transfer catheter is inserted into the cylinder axis. Testing results have shown that, the seed activity can be estimated with a precision better than 5 % when it is positioned in front of one of the two dosimetric probes. This positioning is chosen to estimate the dose with the highest measurement SNR and the lowest sensitivity on seed positioning errors (There is a low dose rate gradient when the seed is facing the probe). With the acquisition of a treatment plan used as a reference, the dwell position can be estimated with sub-millimetric accuracy over a range of 20 mm, and the dwell time with a mean error of 24 ms. It also integrates measurements of the transit time during the introduction and removal of the source. Thus, it is possible to define the dose at any point in space from the activity reference source by using the dose calculation formalism TG-43 AAPM-ESTRO consensus [2]. The difference between the dose calculated by the system software and the TPS is less than 4% for the considered points of interest. The proposed system allows an entire quality check of the afterloader before treatment. By comparing measured values with expected ones, it also allows real-time detection of different types of errors such as bad source activity, treatment protocol error, in-catheter curvature-induced position errors [3].

Keywords: Brachytherapy, DoGaN, Quality assurance

References

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ESTABLISHMENT OF DOSIMETRIC REFERENCES IN SMALL FIELDS thanks to a new quantity of interest


Introduction: The output factor ratio measurement assumes that the calibration factor of the ionization chamber in terms of absorbed dose to water is invariant with field size. A new approach was suggested in order to verify that this hypothesis is true for a parallel-plate chamber which sensitive volume is larger than the beam’s section. The quantity of interest is then no longer a dose at a point but a dose integrated over a surface.

Methods: A graphite calorimeter and a parallel-plate ionization chamber with the same sensitive volume (3 cm diameter) were built. They were fully characterized in a large 60Co beam and then used in small circular fields of 2, 1 and 0.75 cm diameter. The ratio of calorimetric against ionometric measurements was considered as a good approximation of the calibration factor and thus studied.

Results: The dose rate established in a large 60Co field with the new calorimeter is in agreement within 0.4% with previous calorimeters. The ionization chamber shows good characteristics except for a 0.06% drift per hour in water. In small fields, statistical uncertainty on the ratio considered increases with decreasing field size but stays under 0.5%. A difference of 1.3% of this ratio was found for the three field sizes of interest.

Conclusion: Results presented here highlight the possibility of measuring calibration factors in small fields using a dose-area product. Monte Carlo simulations are underway in order to precisely determine the calibration factor of the parallel plate chamber in the three small fields studied.

Keywords: Radiotherapy, Dosimetric reference, Small fields; Dose-area product

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POSTERS

P-26. OF THE USE OF NEW EBT3 FOR DOSE PROFILE AND DOSE-AREA PRODUCT MEASUREMENTS IN SMALL FIELDS


Introduction: The calibration in small fields of a dosimeter which sensitive volume is larger than the field is possible thanks to the use of a new quantity of interest in radiotherapy: the dose-area product. If a relative dose profile of the beam is well known, it is then possible to calculate the absorbed dose at a point. Because of their good spatial resolution and nearly water equivalence, EBT3 films were chosen to get a 2D dose distribution in several small fields.

Methods: EBT3 were fully characterized: the response versus energy, dose-rate and dose was investigated. Profiles measured in circular field with a diameter of 2, 1 and 0.75 cm were compared to the ones measured with a PinPoint ionization chamber, a diamond detector developed at CEA; LIST/LCD and a diode. In the 2 cm diameter field, the ratio of integrals of dose over a 0.6 cm and 3 cm diameter surface was compared to the ratio measured with calorimeters and calculated with Monte Carlo simulations.

Results: EBT3 are dose rate independent but their calibration curve varies with the energy of considered beam, suggesting an underestimation at low energies. Films and diamond profiles are in good agreement but differences appear with the other dosimeters. The ratio of integrals of dose between films, calorimetry and simulations is within 1%.

Conclusion: Characteristics of EBT3 make them a potential candidate for the measurement of relative dose distribution in small fields. This kind of measurement stays nevertheless delicate which strengthens the interest of a dose-area product over a dose at a point.

Keywords: Radiotherapy, Dosimetric reference; Small fields; Dose-area product; EBT3

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P-27. PREDICTION METHOD OF SENSORS RESPONSE POSITIONED AT THE SURFACE WITH AND WITHOUT LATERAL ELECTRONIC EQUILIBRIUM IN CONFORMAL ARCTHERAPY

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Introduction: This study is in line with the inverse method for IVD in conformal arctherapy for stereotactic radiosurgery previously developed (SPM-2013). The present work describes an experimental method enabling the response of a detector positioned on the surface and irradiated through an arc with and without lateral electronic equilibrium to be predicted.

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Material and methods: This study was performed on a Novalis 600N (µMLC m3, BrainLab) with MOSFET sensors (TN-502-RD,BestMedical) calibrated with a local method (SFPM-2010). Sensor equipped with a RW3 cap was positioned at the spherical phantom surface of Lucy/3D-QA (Standard Imaging). Then the position of the detector was changed by stages away from the axis using the arm of the accelerator to entry angles (Standard Imaging). Then the position of the detector was changed by stages away from the axis using the arm of the accelerator to entry angles (Standard Imaging).

Results: For all field sizes studied a good correlation was observed between the measured angular profiles interpolated at entry and exit and the dose profiles calculated by TPS: the risk value α remained low, i.e. p < 0.05.

Conclusion: These results validated the method of experimental determination of angular profiles with and without lateral electronic equilibrium. The next stage of the investigation will be the Monte-Carlo simulation of MOSFET sensors and to extend the method to other sensors.

Keywords: Stereotactic radiosurgery, In vivo dosimetry, Inverse-problem

Material and methods: The Cyberknife (G4) delivers a 6 MV photon beam at a 600 UM/min dose. 10, 30 and 60 cm field size collimators has been used. Treatment planning is performed on a 3.52 Multilplan version using dose computation matrix 256x256 for the FMCA. Radiochromic films have been scanned with an Epson perfection V750 Pro, 48H after irradiation with a 72 dpi resolution. Concerning the calibration, it has been performed according to the recommendation of the AAPM. Multicanal correction has been applied. Checking FMCA beam modeling with measurements has been performed on a homogeneous PMMA phantom. Two heterosexual phantoms have been designed to study the limits of the FMCA. One made of a stack of ICRU equivalents materials: adipose (ρ = 0.92 g.cm-3), Bone (ρ = 1.85 g.cm-3) and PMMA (ρ = 1.19 g.cm-3) slabs. Another one made of an air cavity inside a PMMA phantom. As a second method to get a reference dose map, we used the MCNPX ab-initio Monte Carlo Code. To analyze the different results accordance, we rely on dose depth profile comparison.

Results: As expected, dose deposition in a homogeneous phantom calculated with FMCA remains within a range of ±1% of the dose measured. The air-gap phantom shows that FMCA obviously consider the presence of heterogeneity even though the calculated dose remains up to 30% higher than the measured one. For over dense heterogeneities neither RTA nor FMCA are able to calculate the right dose deposition. Even though FMCA calculation doesn’t consider correctly the bone heterogeneity, MCNPX simulation can. This comfort the quality of experimental measurement.

Conclusion: We highlight in this study the limits of the FMCA in the presence of overdense heterogeneities. These latter kinds of heterogeneities are simply not considered in the calculation even though underdense heterogeneities are considered in the dose computation.

Keywords: Monte Carlo, Cyberknife, Heterogeneity
The CS approach was validated through a single parametric setting: a parallelepiped cavity of size 300 mm × 600 mm. This simulated case corresponded to 6MV photon beam radiation with a 11 cm² field size. The same cavity was filled successively with six different materials: H2O, Si, Ge, Al2O3, GaN, GaP.

This method was evaluated to reduce the simulation time by up to 6 folds compared to separate simulations of 6 materials. This meant that the additional process steps related to method implementation did not increase significantly simulation time for the tested setting.

We are also working on the integration of other variance reduction techniques such as splitting [3] with CS method for further reducing statistical uncertainty. The achieved efficiency is under evaluation.

Keywords: Monte Carlo, Penelope, Correlated sampling

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P-34.

USE OF EBT3 GAFCHROMIC FILMS FOR MONTE CARLO VALIDATION OF CYBERKNIFE™ TREATMENT PLAN

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Purpose: Validation of Monte Carlo (MC) algorithm commissioned in Multiplan™ using EBT3 Gafchromic films.

Materials and methods: Two phantoms were used for MC validation, the Baby blue and a thoracic phantom, representing homogeneous and inhomogeneous media respectively. They were scanned using the Brilliance Big Bore™. Treatment plans were created on the Multiplan™ 4.8 software (Accuray). The tracking modality was based on fiducials for the homogeneous phantom and on spine for the thoracic one.

In one part of the study, treatment plan and its delivery for single anterior fields were performed for 20 patients. Then plans were recalculated with Acuros 13.5.03 XB (AXB) algorithm. PTV : conformity index CI(100 %), CI(50%), MaxD(%) in dose prescribed to 2cm.

Results: For the 10 patients with peripheral tumors, we got CI(100%) AAA = 1 ± 0.06, CI(100%) AXB = 0.97 ± 0.06, CI(50%) AAA = 4.48 ± 0.49, CI(50%) AXB = 4.4 ± 0.49, MaxD to 2cm (%) AAA = 57.5 ± 6.1 MaxD to 2cm (%) AXB = 57.17 ± 6.1. For the 10 patients with central tumors, we got CI(100%) AAA = 1.06 ± 0.7, CI(100%) AXB = 0.42 ± 0.24, CI(50%) AAA = 5.31 ± 1.11, CI(50%) AXB = 4.83 ± 1.1 to 2cm MaxD (%) AAA = 55.4 ± 9.2, MaxD to 2cm (%) AXB = 55 ± 9.1.

Doses to organs at risk for 20 patients yielded similar results for both algorithms.

Conclusion: Based on the results, we can say that the AAA algorithm can be used to calculate the treatments plans when the tumor is in the parietal or mediastinal situation. On intra parenchymal tumors, it is not accurate enough to be used for these treatments. Further analyses are in progress for the quantification of differences in dose volume histograms for the PTV and ITV.

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P-35.

NEW RADIOISOTOPES HDR BRACHYTHERAPY DOSE

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Introduction: Brachytherapy was born with the discovery of ionizing radiation and radium was first used at the beginning of the twentieth century. After the discovery of the artificial radionuclides 137Cs and 192Ir came to accompany and then replace the Radium. With the development of high dose rate, the 192Ir took a very important part now rivaled by 60Co and may be tomorrow by the 169Yb or 170Tm.

Materials and methods: Using data from the literature and the formula for calculating the dose of TG43, the radial functions and anisotropy are compared for several radionuclides: 60Co, 137Cs, 192Ir, 170Tm and 169Yb. The distance factor is the same for all and it is assumed that the dose rate is also the same.
Results: The table of values of the radial function shows similar values for the first three radioelements. Moreover values vary little (8%) of 5 cm in the vicinity of the source. The dose distribution is mainly due to the geometric function (Law 1 / d^2). For two other radioaunclides whose photon energy is lower (on average 84 and 93 keV), the radial function plays a more important role (maximum value 1.4 for the 170Tm). This leads to a better homogeneity of the dose in the region of interest. The period of 129 days makes it more interesting than the 192Ir unlike 169Yb shorter period (32 days).

Conclusion: The interest of new radioaunclides studied is mainly due to a radial function whose values are more important in the first few centimeters. Thulium also has the advantage of having a longer than iridium which will reduce the number of changes of period sources. It remains to be validated production costs and the possibility of obtaining dose rate at least equivalent to those of 192Ir.

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SESSION: QUALITY CONTROL – RISK MANAGEMENT

ORAL COMMUNICATIONS

RISK ANALYSIS IN RADIOTHERAPY: A VALUABLE GOAL
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In order to improve healthcare security, since the 25th of March 2011 the radiotherapy units have been required by the ASN to increase their involvement in safety management. They were especially required to do a risk analysis and to improve healthcare safety. Inspections (ASN, 2011) have revealed that this requirement was not thoroughly satisfied. The documentary analysis of thirteen risk cartographies (IRSN, 2012) has confirmed that it was difficult to fulfill this requirement and that the aim of this approach was thus only partially reached. Based on these findings, in the year 2013 the ASN has asked the IRSN to better identify the difficulties that were encountered by the radiotherapy units. In the course of the year 2013, the documentary analysis of the thirteen risk cartographies (IRSN, 2012) was complemented by the study of data sampled in the answers to a questionnaire that had been sent to all the radiotherapy units and by a study carried out in three different sites. This site study has consisted in observing the functioning of working groups in charge of the risk analysis and in organizing talks with one another.

Various types of difficulty were identified as a result of that study. On the one hand, there were difficulties in the evaluation of the consequences of the detected failings and in their expression in term of risks. On the other hand, difficulties aroused to establish a scale of risk and to define a level of priority among the corrective actions to be taken. Moreover, it was difficult for the radiotherapy units to evaluate the result of the actions undertaken for improvement. Beyond the complexity of the approach and the fact that the mastering of the methodology may suffer from some insufficiencies, this study has also revealed that the resources and competence of the radiotherapy units were not adequately adapted with what was expected from the risk investigations.

As a result of that study, the IRSN has proposed to work in three main directions: i) to better guide and accompany the radiotherapy units, ii) to reduce the complexity of the risk investigations and iii) to think up more efficient models of risk management for their utilization by the radiotherapy units.

Keywords: Risk analysis, Healthcare safety, Human and organizational factors

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POSTERS

P-37.
PROPOSAL FOR A CRITERION TO CHOOSE BETWEEN A DIRECT OR INDIRECT EVALUATION OF EYE LENS DOSES
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Introduction: These last years, a lot of articles and oral communications or poster during conferences dealt with eye lens dosimetry. Today, it is unanimously agreed that eye lens doses must be measured but the modalities of its implementation make debate. A few dosimeters specially designed to be worn close to the eye lens are available. Having to wear a dosimeter close to the eye lens can be annoying. Therefore, it is necessary to verify if the use of a dosimeter worn at the level of the lens is essential, to allow a direct evaluation of the dose to the eye lens, or if an indirect evaluation via, for example, a whole body dosimeter, worn on the trunk, is possible.

Material and method: Let’s define the ratio R as $H_p(3)/H_p(10)$, this formula allows deriving $H_p(3)$ from the $H_p(10)$ measures. Taking into account the limit of exposure for $H_p(3)$, 20 mSv on average over 5 years or 50 mSv over one year, one can substitute $H_p(3)$ for these exposure limits to define a maximum value of $H_p(10)$ such as:

$$H_p(10)_{\text{max20}} = 20/R$$

$$H_p(10)_{\text{max50}} = 50/R$$

(eq.1)

Considering the extended uncertainty $U(H_p(10))$ on the measure of $H_p(10)$, one can change equations 1 as:

$$H_p(10)_{\text{max20}} + U(H_p(10)) = 20/R$$

$$H_p(10)_{\text{max50}} + U(H_p(10)) = 50/R - U(H_p(10))$$

(eq.2)

Thus, if the measure value of $H_p(10)$ is lower than $H_p(10)_{\text{max}}$, the limit in terms of $H_p(3)$ cannot be exceeded.

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The report EUR 14852 gives the trumpet curves defining the maximum error allowed depending on the measured values of $H_p(10)$. Taking these error as the extended uncertainty in equations 2, one can fit general equations to derive the limit of using a direct measure of $H_p(3)$.

**Results:** This method allows plotting the graph here after giving the value of $H_p(10)\text{max}$ as a function of $R$, the method could also be used for an evaluation of $H_p(10)$ from $H_p(10)$ but for this last case the critical point is the determination of $R$.

**Purpose:** Currently, the models developed for the calculation of out-of-field dose by the INSERM team do not include the component of dose due to leakage radiation from linear accelerators. The objective of this workshop was to participate in the development of an analytical model for the calculation of the dose away from this component. A detailed modeling work was to participate in the development of an analytical model for the calculation of the dose away from this component. A detailed modeling is used, based on a multi-source and inspired a rectilinear fictional source approach.

**Materials and methods:** This study was conducted in two stages. A first experimental part made for beams of $6\text{ MV}$ X-ray of two types of linear accelerator Novalis Tx (Varian) and Primus (Siemens), measurements of doses delivered to points at different distances from the beam axis for configuration at null field are presented and compared to the IEC standard. Dosimeters are used thermoluminescent dosimeters TLD-700 type compounds LiF powder doped Mg and Ti. The second part is to illustrate the formalism developed for the model. The measured leakage is then separated into two components by their dependence on the field size.

**Results and discussion:** From a quantitative point of view, the leakage radiation for both devices is consistent with the limitations prescribed by the IEC. From a qualitative point of view, the leakage radiation from the primary collimator on the rapid decrease in dose decreases with the field size.

**Conclusion and perspectives:** This model is capable of estimating the distance dose coming from the leakage radiation of the treatment device by taking into account two parameters which are the field size and the distance from the beam axis. Currently, only the dose due to the leakage radiation is taken under consideration in the calculated doses. This work will have to be added to those devoted to the modeling of other components of the peripheral dose, in order to have a complete model, capable of estimating the total distance dose. A consideration of other photonic interactions in the collimators as well as more sophisticated algorithms would increase both accuracy and performance of this code to make it compatible with clinical practice eventually.

**Keywords:** Leakage radiation, Diffusion collimator, Dose distance, Measurement with TLD-700, Dose calculation and multi-source approach.

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**P.38.**

**MODELING THE DOSE DISTRIBUTION CAUSED BY LEAKAGE RADIATION FROM THE LINEAR ACCELERATOR FOR EXTERNAL RADIOTHERAPY**

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**Purpose:** This study was conducted in two stages. A first experimental part made for beams of $6\text{ MV}$ X-ray of two types of linear accelerator Novalis Tx (Varian) and Primus (Siemens), measurements of doses delivered to points at different distances from the beam axis for configuration at null field are presented and compared to the IEC standard. Dosimeters are used thermoluminescent dosimeters TLD-700 type compounds LiF powder doped Mg and Ti. The second part is to illustrate the formalism developed for the model. The measured leakage is then separated into two components by their dependence on the field size.

**Materials and methods:** This study was conducted in two stages. A first experimental part made for beams of $6\text{ MV}$ X-ray of two types of linear accelerator Novalis Tx (Varian) and Primus (Siemens), measurements of doses delivered to points at different distances from the beam axis for configuration at null field are presented and compared to the IEC standard. Dosimeters are used thermoluminescent dosimeters TLD-700 type compounds LiF powder doped Mg and Ti. The second part is to illustrate the formalism developed for the model. The measured leakage is then separated into two components by their dependence on the field size.

**Results and discussion:** From a quantitative point of view, the leakage radiation for both devices is consistent with the limitations prescribed by the IEC. From a qualitative point of view, the leakage radiation from the primary collimator on the rapid decrease in dose decreases with the field size.

**Conclusion and perspectives:** This model is capable of estimating the distance dose coming from the leakage radiation of the treatment device by taking into account two parameters which are the field size and the distance from the beam axis. Currently, only the dose due to the leakage radiation is taken under consideration in the calculated doses. This work will have to be added to those devoted to the modeling of other components of the peripheral dose, in order to have a complete model, capable of estimating the total distance dose. A consideration of other photonic interactions in the collimators as well as more sophisticated algorithms would increase both accuracy and performance of this code to make it compatible with clinical practice eventually.

**Keywords:** Leakage radiation, Diffusion collimator, Dose distance, Measurement with TLD-700, Dose calculation and multi-source approach.

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**SESSION:** RADIOTHERAPY (TRANSIT DOSIMETRY, QUALITY CONTROL OF TREATMENT PLANS)

**INVITED COMMUNICATIONS**

**TRANSIT DOSIMETRY: THE STATE OF THE ART**

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**Introduction:** The technical developments in radiotherapy equipment have inserted many innovations in physics, preparation and treatment domains. Currently three different techniques are at disposal to provide in vivo dosimetry: IGRT, skin measurement, and portal dosimetry. They are already leading radiotherapy in the era of adaptation which will require many years of implementation.

**Materials and methods:** The transit dosimetry consists in measuring the dose delivered using the portal imager with the patient on the treatment table. The measurement is possible with a specific portal calibration to take into account the primary beam and the variations of the scattered radiation. The evaluation is performed by comparison with the dose distribution calculated by the treatment planning system (TPS). The evaluations possibility concerns a dose at a central point, a two-dimensional or three-dimensional mapping in the CT image reconstruction. Since the dosimetric comparison is a two-dimensional reconstruction, it requires a software and a calculation model of the same type as provided with a TPS.

**Discussion, conclusion:** If the conventional in vivo dosimetry, using a small point detector on the skin, has shown the direction to an eventually secure treatment, it stays used with large tolerances. On the other hand, the dose to the skin is far from internal anatomic areas of interest which are the target volumes and sensitive internal organs. The transit dosimetry leads to a dosimetric reconstruction in the patient three-dimensional images to assess much more than to simply filter technical and methodological errors. It provides high levels of secured radiotherapy. It also opens the field of adaptive radiotherapy which tries to take into account all the variations during in the course of treatment and during each session.

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**ORAL COMMUNICATIONS**

**TRANSIT DOSIMETRY FOR TREATMENT IN DYNAMIC ARC THERAPY: EVALUATION OF CLINICAL RESULTS**

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**Introduction:** Transit dosimetry by means of portal imaging devices allows effective and efficient in vivo dosimetry for classical and complex techniques like intensity modulated radiation therapy (IMRT) and dynamic arc therapy. The EPIgray software (Dosisoft) is reconstructing the dose at the points of interest from the transmitted signal recorded during the treatment session. Preliminary analysis of patient results shows a -3% systematic discrepancy between the calculated dose from the TPS (DTPS) and the reconstructed dose (DR).

The aim of this work is to identify the cause of this difference and to determine which of these two values is the closest from the true value.
Materials & methods: 30 patients have been treated on a CLINAC 2100 with dynamic arc therapy (6MV beam). The dose calculations were performed using ECLIPSE (V10) (Varian) with AAA algorithm. Regarding transit dosimetry the EPIGray software was used (V2.0.3) which allows to reconstruct the dose delivered to the patient by means of the transmitted signal acquired in “cine” mode during the treatment session.

The evaluation was performed with COMPASS software (V3.0.2) (IBA). This system allows performing an independent computation of the dose distribution on the planning CT using a Collapse Cone Convolution Superposition algorithm. The dose may be calculated using either the fluence computed by the TPS (DCalc) or the real fluence measured in the beam with a 2D detector (MatriXX) (DMes). The doses at the reference points are then compared in the two cases.

Preliminary results: Preliminary results show that there is no significant difference between \( D_{\text{TTPS}} \) and \( D_{\text{Calc}} \) at the reference point locations (average difference = 0.1%). The results concerning the differences between \( D_{\text{TPS}} \), \( D_{\text{Calc}} \), and \( D_{\text{DMes}} \) are still under evaluation and will be reported.

Conclusion: Preliminary results show that there is no systematic difference between \( D_{\text{TPS}} \) and \( D_{\text{Calc}} \) when the fluence from the TPS is used for the independent calculation. The results concerning the measured fluence under the machine \( D_{\text{DMes}} \) are still under analysis but they will be presented during the communication.

Keywords: Transit dosimetry, Dynamic arc therapy, Quality control

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DEVELOPMENT OF A NEW VIRTUAL SOURCE MODEL FOR PORTAL IMAGE PREDICTION USING THE MONTE CARLO CODE PENELOPE

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Purpose: Electronic Portal Imaging Devices (EPIDs) are widely used for quality assurance and dosimetric verifications in radiotherapy. To highlight dose delivery errors, the image acquired during the treatment session can be compared to a pre-calculated reference image, which can be predicted at high-resolution with a recently developed Monte Carlo (MC)-based method. However, using this method in clinical routine is still hampered by the necessity to store huge phase space files (PSF). This study aims at developing a new and accurate virtual source model (VSM) to describe in a compact way the irradiation beam by keeping all the correlations between particle characteristics stored in the PSF.

Material/methods: The VSM was built upon a commissioned model of a Synergy linac (Elekta) developed using the PENELOPE code. Using this model, a reference PSF was calculated for an uncollimated beam after the flattening filter (FF), and particles were sorted out in three sub-sources according to the position of their last interaction in the linac head (target, primary collimator or FF). Each particle is described by its radial position (\( r \)) in the PSF, its energy (E), and its polar and azimuthal angles (phi, th), representing the particle deviation compared to its direction after bremsstrahlung, and the orientation of this deviation. For each sub-source, a 4D histogram was built by storing the particle distributions according to their \( r \), E, phi, th values. Our VSM hence contains all correlations between these four variables. This new VSM was implemented in PENELOPE, and was validated by comparing physical characteristics from the reference PSF and from the VSM. Then calculated dose distributions in a water phantom were compared for an uncollimated beam using the VSM and the reference PSF. Energy spectra and angular distributions in PENELOPE coordinate system obtained for each sub-source with the reference PSF and with the VSM are compared. The VSM reproduces with an overall good agreement the energy and angular distributions of the reference PSF. Figure 1 shows for each sub-source depth dose and lateral dose profiles in the water tank located just after the flattening filter. Good agreements are observed between the dose distributions calculated with the VSM and the reference PSF. Results remain sensitive to the chosen binning for the correlated histograms, and binning optimization is under study to provide the most accurate results.

Conclusion: A new VSM taking into account for all correlations between particle characteristics was developed and implemented in PENELOPE. Its accuracy will make it usable to calculate high-resolution reference portal images and dose distributions for quality assurance in radiotherapy.

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2D/3D EPID-BASED IN-VIVO DOSE RECONSTRUCTION FOR DYNAMIC IMRT TREATMENTS

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Introduction: The purpose of our work was to develop, test and evaluate an EPID-based back-projection algorithm to perform 2D and 3D in-vivo dosimetry for dynamic IMRT (dIMRT) treatments.

Material and methods: The model, developed in Matlab™ VR2012b, was created for an as-500/2 (Varian Medical System™, Palo Alto, CA, USA) and a 6-MV photon beam energy. Grayscale pixel values are first converted into dose thanks to a dose response function and deconvolute with a field size dependence kernel. Then, the primary dose at the EPID level (estimated from patient transmission 1.2) is backprojected in a plan parallel to the EPID, through the isocenter. Finally, the patient scattered contribution is estimated and added in order to obtain a complete 2D dose distribution. 3D dose reconstruction is performed using an attenuation correction function estimated from the calculation depth and including a build-up modeling. 30 beams distributed over 8 whole brains treated by 3DCRT and 22 Head & Neck (H&N) dIMRT fields were selected for the 2D evaluation. 3 validation steps were defined which are:

- Pretreatment (i.e. without patient placed between the source and the EPID)
- In-Phantom (the dose is reconstructed in a 15-cm thick water equivalent slab phantom)
- In-vivo (i.e. in real treatment conditions)
The 3D dose reconstruction was evaluated by reconstructing the total dose delivered by a 5 dIMRT fields from a H&N plan in the patient. For each dose reconstruction, the dose calculated from EPID signal was compared with the TPS calculation (Eclipse® v.10) using the γ-evaluation method with 3% of the maximum dose delivered as dose difference criterion and 3mm as distance-to-agreement criterion.

Results: Whatever the step of validation and/or the treatment technique, the average of points satisfying the chosen γ-criteria (Global 3%-3mm) was always superior to 95% (Pretreatment: 98.4%, In-Phantom: 99.7%, In-vivo: 95.3%) proving the feasibility of using the developed algorithm for in-vivo purpose.

Conclusion: Results obtained here confirm that the developed algorithm is able to reconstruct the dose received by the patient during his treatment session in 2D and 3D for dIMRT plans.

References

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IMPLEMENTATION OF THE TRANSIT DOSIMETRY WITH EPIGRAY, A DEDICATED SOFTWARE FOR VMAT TREATMENTS
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Purpose: This work presents the implementation and the first results obtained with EPIgray software for in vivo measurements by transit portal dosimetry for VMAT treatments (Volumetric Arctherapy Technique).

Materials and methods: The method is based on the reconstruction of the dose in the patient from images acquired in cine mode (continuous mode) during the VMAT treatment, according to the formalism developed by the Institute Curie (P. Francois et al., PMB 2011, vol 27).

In the first step, the parameters of acquisition in the IAS3 (<frames per second>- <frames by image>- <frames per second>) were studied. In the second time, measurements of dose delivered by transit by the imaging device were performed on a cylindrical phantom for head-and-neck and Pelvis VMAT plans of treatment. The measures were made at the isocenter and were compared with the measure of absolute dose obtained with an ionization chamber PTW Semilix 0.125 cm². Finally a set of measurements on patients allowed to define statistics of the variations noted between the expected dose and the reconstructed dose in the patient for 3 points located in the target volume or in the critical organs. Measurements were repeated during the first three sessions to evaluate the reproducibility of the process.

Results: The training of the mode « movies » allowed us to quickly have results on a cylindrical phantom. On phantom, the gap between the expected dose and the reconstructed dose was of -1.1% on average (standard deviation: 1.05%). This measurement is in correlation with the measure obtained with the ionization chamber. The results on the patients show that 90% of results lie between -5% and +5%, with an average of -0.2% (results out of 12 patients).

Conclusion: The transit dosimetry for the VMAT treatments is a new system allowing the reconstruction of the dose in the patient in various points. This technique of in vivo dosimetry allows the detection of possible errors of the VMAT plan of treatment and could make it possible to be free from pretreatment measurements on phantom.

Keywords: In vivo dosimetry, Transit dosimetry, VMAT

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IN VIVO DOSIMETRY FOR INTRAOPERATIVE RADIOTHERAPY FOR BREAST CANCER
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Introduction: The aim of our study is to work the feasibility of routine measurements of an in vivo dosimetry system: DosiSecure® based on MOSFET technology, during intraoperative breast irradiation. The DosiMeV® of DosiSecure® used more commonly to perform the IVD of electron radiotherapy was studied experimentally for use in X-rays of low energy.

Materials and methods: The device used for operative procedures is an Intrabeam® (Carl Zeiss Medical, Germany) which uses X-rays with an accelerating voltage of 50kV (mean energy spectrum 20 keV). A DosiMeV® calibration has been done for this specific radiation. Then, depth-dose, repeatability, reproducibility and angular dependence of the DosiMeV® were evaluated. The effect of radio-transparency was also investigated.

These measurements were carried out using a 35 mm diameter applicator, since it is the most commonly used.

The first clinical measurements allowed to evaluate the intra-cavity dose and the skin dose during a standard procedure (20 Gy). The control of the dose deposited in the skin seems to be more interesting to assess the importance of side effects.

Results: Depth-dose measurements with DosiMeV® corresponds quite well with the theoretical data with a maximal gap of 6%. The variation coefficient of repeatability was estimated at 0.4%. The variation coefficient of reproducibility was estimated at 0.6%. Angular variations results are pending. Average results from 5 clinical applications gave a mean intra-cavity dose of 20.66 Gy and a mean skin dose of 1.49 Gy.

Conclusion: The use of a DosiMeV® to perform the IVD on Intrabeam® technology seems to be conclusive. The first experimental results appear to be satisfactory and, to confirm them, 20 to 25 more patients will be added to the present study from now till June.

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PER STRUCTURE GAMMA INDEX AND DVHS ANALYSIS: A NEW APPROACH FOR IMRT PLANS VALIDATION?
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Introduction: Current intensity modulated radiation therapy (IMRT) quality assurance software offer new tools such as the ability to make a per structure gamma index (GI) analysis, and compare computed dose volume histograms (DVHs), obtained by measurements and by the treatment planning system (TPS), in order to make a more clinical analysis of obtained results and to consider a new way of IMRT treatment plans validation.

Materials and methods: A retrospective study on 50 head-and-neck patients, treated in step & shoot on a Beam Modulator Synergy Platform (Elekta) linac, has been carried out with the DVHPro module of the Scanditrons Delta4 software. RT structure files were exported from the Pinnacle® v9.2 (Phillips) TPS to the Scanditrons Delta4 software. A local GI analysis was performed on the plan, PTVs (tumor and nodes) and several organs at risk (spinal cord (SC) and parotids). Structures gamma index passing rate (%GP) were recorded for several criteria sets: ±3%-3mm, ±2%-2mm and ±1%-1mm. Percentage dose difference (%DE) between DVHs computed in the phantom, obtained by the TPS and by the measurements, were calculated for different structures : PTV (D95%, Dmean), SC (D2%) and parotids (Dmean). Obtained %DE data was plotted as a function of %GP data for all the selected structures and criteria sets, in order to see if an eventual relationship existed between those 2 data sets. The quality of obtained
results has been clinically evaluated on the basis of a dose error ±3% between DVHs.

Results: Firstly, this study highlighted the fact that a %GP>95% does not assure a %GP>95% for all structures, and reciprocally. Secondly, this study did not highlight a clear relationship between structures GP% and DE%, excepting a slight linear tendency that can be seen for PTVs Dmean.

Conclusion: Plan and per structure gamma index analysis does not predict clinically relevant results, and a DVHs analysis is almost essential.

Keywords: Gamma-index, Structures, DVH

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A 3D QUANTITATIVE EVALUATION FOR ASSESSING THE CHANGES OF TREATMENT PLANNING SYSTEM AND IRRADIATION TECHNIQUES IN RADIOTHERAPY

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Purpose: This work proposes a 3D global evaluation for assessing the alterations introduced by the change of dose calculation algorithms or the change of irradiation techniques for radiation therapy. The comparison includes the Planning Target Volumes (PTV) and Organs at Risk (OAR).

Materials and methods: This method compares two treatment plans: the reference plan (Dr) using the current technique and the tested plan (Dt) using the novel technique. We applied this method for two different situations: the change of dose calculation algorithms for lung cancer and the change of irradiation techniques for breast cancer. The global analysis is based on γ-index and χ-index. The DICOM images, for reference and tested plans, including the PTV and OAR were exported from Eclipse® TPS. In order to discriminate an over from an under estimated dose, a sign was attributed to absolute values of γ and χ indexes, i.e. Dr ≥ Dt had a positive sign and Dr < Dt had a negative sign. The 3D γ and χ maps, the cumulative Gamma Voxels Histograms (GVH) and cumulative Chi Voxels Histograms (CVH) were generated. Pearson’s Chi-squared test was applied to assess the statically significance between GVH and CVH generated by γ and χ indexes.

Results: The γ and χ indexes provide an overall comparison that makes an easier comparison for 3D dose distribution. The γ and χ maps provide a visual comparison of dose distribution. The superposition of maps with the CT scan allows to identify the under or overestimating dose for PTV, and the respect of dose tolerance for OAR. The χ-index evaluation was (-190) times faster than γ-index evaluation. Pearson’s Chi-squared test showed that there was no statically significance difference between GVH and CVH, (p > 0.05).

Conclusion: The evaluation in 3D using γ and χ indexes is well adapted to compare two algorithms or two irradiation techniques. They require only two DICOM images to generate the maps and the cumulative GVH and CVH. The χ-index is a valuable method to following the irradiation of the patient during the treatment. This method could be used for adaptive dosimetry approaches.

Keywords: Dose distributions, Gamma voxels Histograms, Gamma maps.

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USE OF A VIRTUAL BOLUS FOR TBI IN TOMOTHERAPY

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Introduction: To perform Total Body Irradiation (TBI) Tomotherapy allows a better dose homogeneity, a higher accuracy and less dose to Organs at Risk (OAR) than Conventional Radiotherapy (RT). Tomotherapy is a modulated RT. Thus the dose coverage is strictly limited to the target and a set-up margin is added to the target to create PTV. If the target is close to the body surface this margin cannot be added in the air. Then it is possible to use a Virtual Bolus: a material placed on the skin during treatment planning but absent during the treatment. This work proposes to find the optimal thickness and density for a VB to compensate set-up errors without modifying the delivered dose of TBI.

Material & methods: 245 Tomotherapy plans were computed for a cheese phantom using VB with different densities (0 – 1) and different thickness (0 – 30 mm). Phantom and VB are set as targets. To assess the ability of the VB to compensate for set up errors, each plan is calculated by introducing a shift in x direction (0 – 50 mm). PTV coverage (V95 > 95%) and over dosage (dmax, D5%) for all plans are plotted. Dose measurements (ion chamber and detector matrix) are also achieved for all plans.

Results: Without any VB, dose coverage is not insured for a 12 mm shift while a VB allows to compensate set-up errors from 20 to 45 mm depending on its thickness and density. But if thickness is too important, a dmax increase is observed close to the phantom surface (up to 193%) for low density VB and at the center of the phantom for low density VB (up to 116%). For a 5 mm VB with density 0.4 dose coverage is insured up to 23 mm set up error. For this VB, dmax is 123% for a 20 mm shift (113% with no bolus).

Conclusion: The use of VB allows to achieve a modulated RT for target close to the skin by compensate set-up errors and limiting over dosage.

* Corresponding author.

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POSTERS

P-39. ESTABLISHING A GOLDEN DATA SET FOR THE LIBRARY OF A TRANSIT DOSIMETRY SOFTWARE

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Introduction: Transit dosimetry by means of electronic portal imaging devices (EPID) allows effective in vivo measurements for conventional and complex techniques, such as intensity modulated radiotherapy (IMRT) and dynamic arctherapy. The software EPigray of Dosisoft SA, reconstructs the dose at the measurement point from images recorded during treatment. However, the implementation of such a system of transit dosimetry requires specific measures and significant time. Taking into account the increasing standardization of linacs and EPIDs, the establishment of a set of standard- or “golden”- data would minimize the sources of uncertainties and errors associated with the measurements.

Materials and methods: To set up the golden data, the results of the initial measurements of over 15 radiotherapy departments from the database of Dosisoft were compared based on several parameters, such as field size, phantom thickness, and the quality index of the machine. Trends for each combination of parameters were determined. From these assessments, a golden data set could be calculated for different quality indices. Patient and test plans were then calculated with both a “standardized” library and a library created from measured data.

Results: Preliminary results for an energy of 6 MV showed a 1.9% average difference between the dose differences calculated using a standardized library and those obtained with a library made with measurements. This percentage corresponds to an averaged 1.3cGy difference in doses. For energies 10 MV, 15 MV and 20 MV combined, the average difference is 0.7%.

Conclusion: These results obtained with the standardized library validate the creation of a golden data base for the standard EPigray users.

Keywords: In vivo dosimetry, EPi gray, electronic portal imaging device

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P-41. DOSI-MEV® DOSIMETER USED FOR IN VIVO DOSIMETRY OF ELECTRON BEAMS IN EXTERNAL RADIOTHERAPY

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Introduction: Transit dosimetry with an electronic portal imaging device (EPID) allows effective in vivo measurements for conventional and complex techniques, such as intensity modulated radiotherapy (IMRT) and dynamic arctherapy. The software EPigray of Dosisoft SA, reconstructs the dose at the measurement point from images recorded during treatment. However, the implementation of such a system of transit dosimetry requires specific measures and significant time. Taking into account the increasing standardization of linacs and EPIDs, the establishment of a set of standard- or “golden”- data would minimize the sources of uncertainties and errors associated with the measurements.

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Conclusion: These results obtained with the standardized library validate the creation of a golden data base for the standard EPigray users.

Keywords: In vivo dosimetry, EPi gray, electronic portal imaging device

* Corresponding author.

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Introduction: The aim of this work is to assess the performances of a new dosimeter for electron in-vivo dosimetry: Dosi-MeV®. Dosimetric accuracy is evaluated by dose measurements in a phantom and patients.

Materials and methods: The Dosi-Secure® system (TRAD) consists of a wireless tactile reader, a mosfet dosimeter, and an associated soft. This system allows the traceability of each patient during the radiotherapy session. The electron patch of Dosi-Secure®: Dosi-MeV® is based on the technology of Dosi-Patch® photon but is smaller. Dose performances are characterized for a 6MeV electron beam. Detector is placed on the surface of a water equivalent phantom. Repeatability and reproducibility is investigated. Influences of the field size, SSD, angular incidence and debit rate are evaluated. Measurements are compared to the dose measured with an ionization chamber (IC) placed at entrance dose (dmax).

Conclusion: For standard treatment, we were able to implement constraints doses volumes QUANTEC, RTSG, and SFRO. For lung SBRT treatments, RTSG 0813 was successfully implemented. The consistency and coverage of target volumes indexes were configured. The accuracy and efficiency of the program were evaluated by comparing the results with those recorded manually. A slight difference of about 0.25% volume or 0.3 Gy dose between the program and the manual reading was observed. For indices CI (100%), CI (50%) and the dose at 2 cm, there are minimal differences between the two methods. Nevertheless, the evaluation time is reduced by 10-20 min to 2 min using this program.

Keywords: QUANTEC; RTSG; SFRO
Dosimetric index for the PTV (D98, D2, homogeneity and conformity) and OARs (V40 for bone, V20 for skin corridor) quantifies the plan quality.

**Results and conclusions:** The results suggest that using “off-axis” pitches usually improves the plan quality without significant change of treatment time, especially for 5 cm FW plans. The combination FW 5 cm/pitch 0.43 should be avoided whatever the FM, since it gives dramatically bad dosimetric results, without any time gain. The combination FM 1.5/pitch 0.215 or low should also be avoided, since it implies a treatment time increase without any significant dosimetric improvements, due to the rotation speed boundary. Finally, 3 combinations of treatment parameters have been selected according to the operator priority: 5 more patients (2 arms and 3 legs) will be included to complete these preliminary results.

**Keywords:** Tomotherapy, Limb sarcoma, Treatment parameters

**References:**


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<th>V20 Skin Corridor (%)</th>
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