Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Real-Time Motion Tracking, Prediction, and 4D In-vivo Dose Calculation Using Real-time EPID Imaging

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Introduction
Intra-fraction respiratory motion management and normal tissue sparing are essential to delivering a tumoricidal dose to tumours in the thorax and abdomen while preventing damage to healthy tissues. The five year lung cancer survival can be improved by increasing the dose but requires monitoring to ensure optimal patient treatment and safety. Tumour motion can be addressed by expanding the treatment margin, using beam gating or by tumour tracking. Increasing the ITV increases the dose to healthy tissues, breath-hold techniques lengthen the treatment time, while fiducial markers are invasive and can increase the risk of pneumothorax. Indirect systems have a weak correlation between the chest wall and tumour motion. Complex treatment techniques need in vivo patient dose verification to ensure patient safety. Our group has developed a markerless Electronic Portal Imaging Device (EPID) based real-time tumor tracking and prediction technique and 4D in-vivo dose verification, using optical flow algorithms, neural network prediction, and model-based exit-dose reconstruction algorithms.

Materials and Methods
EPID images of uncontoured lung tumour images were collected with an EPID at 2.5 frames/sec, on a 6MV linear accelerator, with both a moving treatment aperture and with a rotating gantry. Motion tracking was achieved using a weighted optical flow algorithm (OFA) to calculate the tumour velocity and position. Prediction to account for system latency was carried out using a Neural Network trained both off-line and using a patient-specific on-line sliding window. Lung tumour motion was simulated using a 3D printed tumour moved by an actuator controlled by LabView. Tumour motion taken from the breathing patterns of seven lung cancer patients was simulated, and corrections for the apparent motion of the tumour due to the rotating gantry were carried out. Using a 4D CT scan of the phantom, a dynamic IMRT plan that tracked the tumour motion was created. The tumour motion and linac delivery were synchronized using an RPM system (Varian Medical Systems) in gating mode with a custom breathing trace. On-treatment EPID frames were captured using a data-acquisition computer with a dedicated frame-grabber. An EPID-based in vivo dose reconstruction model was used to reconstruct the 4D accumulated dose distribution for a dynamic MLC (DMLC) tracking plan using the ten-phase 4D CT dataset. Dose estimation accuracy was assessed for the DMLC tracking plan and a single-phase (50% phase) static tumour plan.

Results
The OFA tracked motion with an average accuracy of better than 0.5mm for both a static treatment gantry with a moving aperture and with a rotating gantry. Motion at the edges of the irradiated field was detected with a tracking error of 0.4±0.3mm and a precision of 1.1mm. The prediction was accurate to within ±1mm and the EPID-based dose reconstruction comparing the DMLC tracking to the TPS calculated static plan gave a 3%/3mm chisop rate of 99.3% for PTV voxels and a mean percentage dose difference of 1.1%.

Conclusions
Real-time EPID-based tumour tracking techniques can improve the conformity of the dose delivered to moving tumours, and will minimize irradiation to the surrounding healthy tissues, sparing critical organs, and lowering toxicities. These approaches show promise for motion management in resource-limited radiotherapy treatments environments.

Keywords: EPID; tracking; 4D dosimetry.
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Software Evaluations of EPID Based Winston-Lutz Measurements

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Introduction
Linacs used for SRS and SBR Treatments require routine and sometimes patient-specific Winston-Lutz (WL) tests to confirm the precision and accuracy of the machine isocentre. EPID based WL measurement is a time and resource saving method; however, analysis of the images by software and the validity of the results are still in question.

Materials and Methods
We aim to investigate the influence of WL marker size (8mm, 5mm, and 3mm diameter ball bearings) and radiation field size (10 x 10cm², 6 x 6 cm², and 2 x 2 cm²) on the WL analyses. Additionally, the results of different analysis software (PTW Iso Check and Sun Nuclear Machine Check) will be compared. We will attempt to determine the validity of the software results by comparing them to film measurements.

Results
The differences between the algorithms used to calculate the WL isocenter make comparisons between the PTW and Sun Nuclear software difficult. The PTW software allows the use of the Minimum Distribution algorithm, which reports the mean WL isocenter of the EPID images and the radius of the isocenter sphere (defined as the difference between the WL isocenter and the measurement point furthest away from it). The Sun Nuclear software reports the maximum deviation from the image centre as the radius of the isocenter sphere. In both software the 6 x 6 cm² and 2x2 cm² resulted in better WL results independent of marker size, for both gantry and couch rotations. More successful ball bearing detections occurred with the 8mm and 5mm WL pointers.

Conclusion
The use of “intermediate” field sizes (i.e. 6x6 cm²) and “intermediate” (i.e. 5mm) WL pointers resulted in better and more successful WL analyses, independent of software, for both gantry and couch motions. Overall, the 3mm WL pointer produced the best results but was also prone to have the most calculation failures. Decreasing the EPID to WL pointer distance was shown to improve calculation success rates.

Keywords: EPID; Winston-Lutz; isocentre.
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Image Guided Radiotherapy (IGRT): A Life Hilton Private Hospital Radiotherapy Unit Experience

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Introduction

IGRT is the use of imaging before and/or during radiation therapy. With the development and implementation of advanced techniques such as VMAT (volumetric arc therapy), IMRT (intensity modulated radiation therapy) and SRS (stereotactic radiosurgery), IGRT has become an essential pre-requisite for delivering high precision radiotherapy. It is essential however that imaging protocols are carefully developed and implemented and all staff are trained adequately.

Materials and Methods

A literature review covering the importance of pre-treatment patient preparation, immobilisation and set-up as well as the different imaging modalities available and their utilisation will be covered. The roles and the responsibilities of the different team members will be discussed. A more practical approach will be explored as to what we currently have within our own unit, here, at Life Hilton Radiotherapy Unit have adopted, and helpful tips, protocols and troubleshooting ideas that we have used in our workplace will be shared.

Results

Daily imaging, if implemented correctly, ensures more accurate delivery of treatment. It also allows for the reduction of PTV margins. When limiting these margins it is critical that correct image matching is performed to limit the possibility of target miss.

Conclusion

Implementing daily IGRT correctly is necessary to ensure accurate delivery of radiation treatment, especially when modulated techniques are implemented, dose escalation is performed and PTV margins are reduced. Well-developed imaging protocols need to be in place as well as sufficient training for staff needs to be performed to ensure treatment is delivered as intended.

Keywords: IGRT, Daily IGRT, Image Guided.
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Electronic Portal Image Detector (EPID) Dosimetry and Calibrations

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Introduction
There has been a steady increase in the utilization of the EPID for dosimetric purposes. Epiqa is a program which uses an algorithm, GLAas, to convert integrated images from the EPID into dose maps to be compared with dose maps from the treatment planning system. The increased utilization of the EPID, leads to more frequent EPID calibration tests.

Materials and Methods
Configuration of the GLAas algorithm required the following; asset of integrated transmission and open fields of different field sizes and monitor units and a set of output factors. This was obtained with the Varian PV-As1000 detector. EPID calibrations include corrections for dark current and flood fields, which tend to overflatten the images from open fields. The GLAas algorithm predicts this response from the detector and corrects for it. If the dark and flood field calibrations are not done regularly, decreased Gamma Index Agreements (GAI) in Rapid Arc quality assurance (QA) can lead to inaccurate assumptions of plan optimization and/or linear accelerator (LINAC) delivery issues. This was seen for certain Rapid Arc plans in our department. Fault finding included creating new plans with different planning and optimization parameters. An increase in GAI was seen for plans, but ultimately, the dark and flood field calibrations were the problem.

Results
Rapid Arc plans were re-measured after recalibration of the dark and flood fields the GAI, for a distance to agreement of 3mm and a dose difference of 3%, increased with a range of 5.5 to 63.4% for seven plans (16 arcs). With the EPID calibrated correctly, we could also make use of the many plan combinations, to determine optimal plan optimization versus LINAC deliverability.

Conclusion
The steady increase in EPID utilization for LINAC and patient specific QA, requires the need for reassessment of the frequency at which EPID calibrations are done. A plan measured directly after these calibrations should be measured at a regular interval, to determine the frequency at which calibrations should be done as this will be EPID specific.

Keywords: Epiqa; EPID calibration; RapidArc.
Validating the Percentage Depth Doses Using Two Different Phantom Materials

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Introduction
Radiation therapy’s success during acceptance, commissioning and quality assurance of linear accelerators lies in accurate collection of data such as Percentage depth doses (PDDs), beam profiles, including output factors using various field sizes and other dosimetric parameters. Dose inside a phantom or a patient is normalized to maximum dose (Dmax) at maximum depth (Zmax) and this is referred to as percentage depth dose (PDD) distribution. PDD relates the absorbed dose deposited by a radiation beam into a medium as it varies with depth along the beam’s central axis.

Aim
Touse RMI457 solid water phantom to conduct a quick PDD check without a need to setup a water tank for various photon energy beams.

Materials and Methods
ELEKTA Synergy Platform, IBA Blue phantom water tank, RMI457 slabs (30x30 cm²), IBA scanning chamber (CC04), PTW electrometer, PTW 30013 Farmer chamber (0.6 cm³), Spirit level, MEPHYSTO 7.4 software. Central axis (CAX) measurements were performed using solid water at different depths with field size (FS = 10x10 cm²) at source to surface distance (SSD = 100cm) with 100MU. The same reference conditions were used for continuous scanning in a water tank. RMI457 solid water phantom was chosen in this study as it has properties close to those of water.

Results and Conclusion
Measurements in solid water compared well to the water tank scans, agreement was within +/-1% at depths beyond zmax. Deviations greater than +/-1% at build-up regions were observed for all photon energies evaluated in this study. These larger deviations at build-up regions are attributed to the cavity size of the ionization chamber, which normally has a larger finite size compared to CC04 chamber. Other factors could be attributed to the displacement of the effective measurement point and all further small perturbations associated with the thin-walled ionization chamber. However, the difference in Zmax values for the two phantoms were well within the acceptable range of ±2mm. The method proposed here, can be used as practical recommendation for a quick dosimetric reference check for PDDs with careful assessment at build-up regions.

Keywords: Percentage depth dose; solid water; RMI457; IAEATRS398; perturbation; effective measurement point.
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Evaluating Stereotactic Treatment Plans with Different dose Prescription Levels

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Introduction
In our company, Stereotactic radiotherapy treatment is linear accelerator based, using 5mm Multileaf Collimator. Rapid dose fall-off is a huge concern and was highlighted in the ICRU91 report. To decrease the dose fall-off region, dose prescription iso dose levels were investigated. Different indices were used namely the Efficiency, Gradient, Conformity and also V12 to compare plans.

Materials and Methods
Retrospectively 10 Stereotactic plans, all 6MV was used for this study. Usually an 80% prescription iso dose level is used, meaning that the prescribed dose, which is 80%, should encompass the PTV. This was varied between 50 and 95%; calculated with a Monaco treatment planning system. The plans were compared and evaluated using different indices.

Results
The dose fall-off is steeper when a lower % dose prescription is used, however, increasing the hotspot. Efficiency index is reported as a percentage and sensitive to the Gradient and Conformity index. Our Efficiency index varied between 20 and 45%, correlating with international standards. The V12 values were all within tolerance.

Conclusion
It seems that a 60% prescription iso dose is more ideal in terms of a steeper dose fall-off and acceptable hotspots. Indexes are a helpful tool to distinguish between plans. However, a clinical observation is still important.

Keywords: Efficiency index; dose fall-off; prescription dose level.
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Demonstration of a 3D Graphics, Interactive Radiotherapy Simulator for Training and Teaching

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Introduction
Familiarity and confidence are important aspects in ensuring that equipment are used properly, with care and to the full ability of the equipment. It is ideal to have a treatment unit available on which staff can learn and practice, but due to the high cost of treatment machines and the need to use the treatment units optimally for patient treatments, it is not possible or feasible to have treatment units idle for staff training. To overcome this problem, an interactive, computer simulation can fill the need. This project involves the development of a computer simulator for Radiotherapy. This simulator aims to address all aspects of Radiotherapy, from basic equipment use, to patient setup, as well as image production.

Materials and Methods
The first step was to determine what aspects were required to be simulated in terms of detail and complexity. The next step was to design 3D models of the selected treatment unit objects. These models were then created using 3D modelling software. These 3D models are then combined and a computer program written to manipulate and control these models to achieve the desired outcomes and realism, as well as to make them interactive.

Results
The radiotherapy simulator is being developed and it will involve multiple phases in order to achieve its full potential. Currently, a generic treatment unit simulation is being used in order to test the functionality.

Conclusion
The computer, graphics simulator has the potential to serve as an independent training aid for a department, not just for learning how to use the equipment, but also as an aid in demonstrating to patients what their treatment will involve in terms of patient setup and machine movements. The simulator also has the potential to be expanded to include other divisions in radiation medicine.

Keywords: Interactive; Simulator; Radiotherapy; Training.
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Medical Physics and Artificial Intelligence-What is Our Role?

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Introduction
As much data is created in just two days as was accumulated from the beginning of civilization until the year 2003. The increase in data volume, variety and velocity presents many opportunities to achieve insights, gain knowledge and accelerate technologies. The use of Artificial Intelligence (AI) is on the rise in the medical field and is already becoming part of the standard of care.

Materials and Methods
AI originally referred to an area of science where machines performed tasks that typically would require human intelligence. Machine learning (ML) is a subset of AI which seeks to derive data-driven decisions by using models built from training data. Deep-learning technologies, a subset of ML, are designed to interpret large data sets, learn from mistakes and improve overtime, making them very robust to changing circumstances. They permit the learning of more complex solutions to correspondingly complex problems.

Results
Deep learning methods have already been applied successfully on various imaging modalities and are gaining popularity in radiation oncology. Efficient data access requires minimized bureaucracy, but at the same time must secure patient confidentiality, as well as legal and ethical compliance.

Conclusion
Medical physicists should develop AI techniques in their field and co-operate with clinicians to translate research results into clinical practice. Big data QA is critical to assess data validity. AI will require updated medical physics training programmes, it will also require a much closer collaboration with IT services.

Keywords: Artificial intelligence; machine learning; deep learning.
Validation of the Beam Scheme Program

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Introduction

Beam Scheme (originally Map Profile) is a program to measure radiation beam parameters such as flatness and symmetry and has been around since 2008 when it was initially written to provide additional information about Map Check profiles. Since then it has been considerably expanded and now supports Map Checktxtfiles, PTW720mcc, IBAMatrix and StarTrackopg, XIO dose planetext files, Eclipse dose plane files, DICOM, jpeg, tif and bmp image files. Although Beam Scheme has always been available for use by the community it was only formally released as open source software (OSS) in December 2017. This release exposed a number of issues, primarily that the parameter set was not consistent and secondly, that there was no formal validation of the parameter calculations. Accordingly an expression parser was added to Beam Scheme to allow the definition of parameter sets and the creation of user-definable parameters. A formal validation process was begun.

Materials and Methods

Beam Scheme was evaluated against myQAFast Track from IBA, PTW Mephs to DataAnalyze, Sun Nuclear Dosimetry and the flatness and symmetry module of pylinac. For each modality, each available parameter set, namely: AFSSAPS-JORF, DIN, IEC-60976, Elekta, Siemens and Varian, was calculated and compared to Beam Scheme for two datasets, one real set and one artificial set. Differences were analyzed and causes determined.

Results

Validation was considerably hampered by the inconsistent implementation of the parameter sets across the different vendors. As a result of the validation, the automatic grounding of profiles was removed. Field edge, centre, size and penumbra parameters agreed well (≤ 0.01cm) while there was more variation in the flatness and symmetry values. The largest difference was 2.5% in the AFSSAPS-JORF parameter set of the IBAFast Track. Minor differences can be attributed to variations in definition of flattened area, while major differences to implementations of the calculation algorithms.

Conclusion

Beam Scheme can now generate results that are directly comparable to existing programs and has been validated as a tool for analysing radiation beams. Version 0.5 is available from http://openmedphys.org/content/beamscheme.

Keywords: Quality assurance; Flatness; Symmetry.
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Reconstruction of Scattered Radiation-A Novel Source of Image Quality Improvement and Dose Reduction in CT and PET

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Introduction
X-ray and gamma photons deposit energy and scatter when they interact with human tissue. Scattered radiation has historically been considered to be noise, contributing dose to the patient, but providing no useful information. Traditional imaging systems such as Computed Tomography (CT) and Positron Emission Tomography (PET) provide valuable diagnostic information but are a significant contributor to an increasing population dose. With the increasing availability of higher energy-resolution detectors, scatter imaging is becoming feasible. This work will summarise the results of our CT and PET scatter-imaging research. We will illustrate how the scatter-imaging techniques improve our ability to diagnose cancer without the dose or cost penalties associated with multi-modality scanning, can provide attenuation corrections and give an anatomical context to PET, which is otherwise a functional imaging modality.

Methods and Materials
Our initial work in CT used are finessed version of the back projection algorithm to demonstrate that by measuring the energy and position of detected photons we are able to reconstruct images with significantly fewer projections. For scatter reconstruction in PET, generalized Maximum-Likelihood Expectation-Maximization (G*S-MLEM) reconstruction algorithms were developed, which are capable of reconstructing single and dual-scattered photons. The scattering angle, calculated from the energy of each photon using the Compton equation, was used to define two circular arcs (TCA) that encompass the annihilation position. In the zero-degree scattering angle limit, the scattered coincidences approach the true coincidence, and hence, true coincidences are considered a subset of scattered coincidences. To avoid over-correcting for scattered coincidences, the attenuation coefficient was calculated by integrating the differential Klein-Nishina cross-section over a restricted-energy range, accounting only for scattered photons that were not detected. Phantoms containing cold and hot regions with various activities were simulated using the GATE platform. Energy resolutions of 5% to 20% were used to blur the simulated events, with scatter fractions from 10 to 40%. Images were reconstructed using different algorithms with a 350-650keV energy window and the proposed restricted attenuation correction.

Results
Images generated using single scattered coincidences demonstrate that only 70% of annihilation positions were correctly identified, while the generalized dual-scatter GDS-MLEM algorithm encompassed 98% of source positions. The GDS-MLEM has the greatest sensitivity and improved the contrast recovery coefficient and reduced noise by 7.6% to 13.2% and 12.4% to 24.0%, respectively.

Conclusions
This work developed reconstruction algorithms capable of reconstructing CT and PET images using scattered photon coincidences. This approach improves contrast, decreases noise, and eliminates the need for scatter corrections. Using scattered photons lowers the data requirement for an equivalent image quality, reduces scan time, injected dose, and radiation burden. The revised attenuation correction method facilitates dynamic selection of an energy window to provide optimum PET images. The GDS-MLEM approach is less sensitive to energy resolution and shows promise if detector energy resolutions of 12% can be achieved. While this algorithm is an improvement over our earlier approaches, we are currently investigating AI-based CNN deep-learning reconstruction approaches which promise to be even less sensitive to the detector energy resolution.

Keywords: Scatter Radiation; Reconstruction; CT; PET.
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**Comparison of the Lutetium 177Lu (DOTATATE) Kidney Internal Dosimetry for the Tygerberg Hospital Protocol vs DosiSoft Software™**

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**Introduction**

The purpose of the study was to compare the internal dose estimates obtained using Tygerberg Protocol which incorporates an in-house excel for percentage uptake (%IA), Mathematica 8™ for time integrated activity curves (TIACs) and OLINDA/EXM™ software for Organ level dose assessment vs the IAEA supplied DOSISOFT software. The DOSISOFT software has nuclear medicine dedicated software for the dose calculation during targeted radionuclide therapy.

**Materials and Methods**

In order to estimate the dose in the kidneys, the sensitivity factor was needed for DOSISOFT. A hybrid SPECT/CT images were acquired using the NEMA Image quality phantom on the GEHawkeye™. The data was reconstructed on HERMES™ medical systems using the Tygerberg reconstruction protocol. The reconstructed data was imported into the DOSISOFT software to determine the sensitivity value to convert counts into activity. The sensitivity value was input in DOSISOFT™ to estimate kidney dose. The same reconstructed images were used to determine (%IA) and to plot TIAC Cusing Mathematica 8™ to calculate the residence time. The residence time was then used in OLINDA/EXM™ to calculate the kidney absorbed dose. A sample data of four patients injected with ±7.5 GBq Lu177DOTATE (4-cycles) were included in this study.

**Results**

Our absorbed dose results compared very well with the DOSISOFT™ kidney absorbed dose estimation within ±5.0% which validated the Tygerberg protocol. The study showed that the Tygerberg protocol can produce absorbed doses with less than 10% error for the kidneys.

Keywords: DOSISOFT; Lu-177; Dosimetry.
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Results from a Dose Optimization Program in Interventional Radiology at Life Healthcare Hospitals

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Introduction
In December 2014, the Directorate Radiation Control, National Department of Health introduced new license conditions on all x-ray equipment in South Africa used for interventional radiology. This dose optimization program requires, amongst other things, the establishment of diagnostic reference levels (DRL’s) for 26 identified procedures. However, the Life Health care Group made the conscious decision to monitor every single procedure, and not only the identified 26 procedures. This resulted in approximately 200 procedures or procedure combinations being monitored. Radiation protection training was also implemented to the Cathlaband vascular laboratory staff. The training material was CPD accredited at the Health Professions Council (HPCSA) via the Health Sciences Faculty at the University of Cape Town.

Materials and Methods
The materials being used are dose-area-product (DAP) meters, i.e., an ionization chamber inserted in the collimator of the x-ray machine. The DAP reading of every procedure is electronically logged on an Excel spread sheet and submitted on a monthly basis to be analyzed. A statistical tool was developed to identify all those procedures for which the radiation doses are consistently unusually high.

Results
A total of 54700 patient procedures were monitored from August 2015 till December 2018. Results will be presented for the following five interventional procedures, i.e., the coronary angiography (CA), coronary angiography and left ventricular (CA+LV), coronary angiography and angioplasty and stent (CA+ PTCA +Stent), permanent pacemakers, and Endovascular Aortic Aneurism Repair (EVAR) procedures. The DRL results for the above-mentioned five procedures are as follows: CA: 46.2Gy.cm²; CA+LV:55.1Gy.cm², CA+PTCA+Stent:151.6Gy.cm², Permanent pacemakers: 24.4Gy.cm², and EVAR:373.1Gy.cm².

Conclusions
DRL’s will be presented for five interventional radiology procedures, the DRL trends since the implementation of the dose optimization program, and compared with similar studies at other hospitals.

Keywords: Dose optimization; interventional radiology; diagnostic reference level; radiation protection.
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Radiation Dose: “Is it Over Exposures or Incidences or Accidents”: Are We Concerned about Activities of Fellow Professionals in our Field

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Introduction
X-rays are a form of energy, similar to light and radio waves. They are also called radiation. Unlike light waves, x-rays have enough energy to pass through the body. As the radiation moves through the body, it passes through bones, tissues and organs differently, which allows a Radiologist to create images of them (or which allow Radiographers to take/create images for the Radiologists). The radiologist is a specially trained physician who can examine these images on a monitor which allow them to see very fine detail of the structures in the body. High energy x-rays are often used for treatment of cancer malignancies and the Radiation Oncologist is a specialist trained for assessment and treatment of different tumors. In Nuclear Medicine radiation in liquid or gas formation is used to provide diagnostic images for the Nuclear Medicine Physician to use this non-invasive method for different diagnosis. The Medical Physicist takes responsibility of dosimetry and radiation protection services. However, during the use of radiation, an accident may occur. A radiation accident is defined by the International Atomic Energy Agency (IAEA) as an event that has led to significant consequences to people, the environment or the facility. In clinical environment, accident may occur that affect Patients, Public and radiation workers.

Method
In Steve Biko Hospital, a set of event leading to radiation incidences were investigated. Radiation incidences on radiation workers were investigated as and when they occur. Radiation over exposures in interventional radiology was also considered for investigations due to the increased number of incident reports.

Results
As agreed between the regulator and Medical Physics department, the findings of the investigations will be presented at the 57th SAAPMB congress.

Keywords: X-rays; radiation; IAEA-International Atomic Energy Agency.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

The Evaluation of an Algorithmic Model, Created For the Image Guided Radiotherapy Treatment Couch for Integration into the Pinnacle Treatment Planning System

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Introduction
During treatment planning the Linac couch must be added as a structure on the plan, so that its density is taken into account for dose calculations. Scripting is a programming language that supports the writing of programs for a software environment that automate the execution of tasks. Scripting the couch top on the Pinnacle Treatment Planning System (TPS) replaces manual contouring of the couch as a structure, thus streamlining the planning process. The Varian IGRT couch is not regular in shape and the aim was to model the full couch accurately in terms of shape, dimensions, and attenuation characteristics.

Materials and Methods
The actual transmission of the 6MV and 18 MV Linac beams through the Varian IGRT couch top was measured at different gantry angles for three different field sizes on different parts of the treatment couch. These attenuation properties were then used to create a model of the treatment couch which can then be inserted into the treatment plans by the script. Due to the shape of the couch being irregular from superior to inferior, as well as anterior to posterior, the modelling of this shape proved quite challenging and a slice-by-slice approach was used. The user specifies on the TPS where the top of the couch must be and then clicks the button to run the script. The script then determines on which part of the couch each slice is and then draws the relevant couch contour, taking into account any longitudinal and lateral offsets that the user specified.

Results
The couch transmission was measured at gantry angles ranging from 120°-240° through 180°. The couch transmission as determined by the TPS at the same gantry angles after the script was implemented was within ± 0.56% of the measured transmission for the 6MV beam and within ± 0.61% for the 18MV beam.

Conclusion
Scripting the Varian IGRT couch top on Pinnacle was achievable and the script runs fast and reliably. The script is currently being tested clinically and will then be made available to departments running the Pinnacle treatment planning system.

Keywords: Pinnacle; Couch; Scripting.

https://globalmedicalphysics.org/
GLAaS First Multicenter Experience on Halcyon Linac: Portal Dosimetry Algorithm Validation and Its Application to Patient Pre-Treatment QA

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4. Varian Halcyon, a 6MV FFF linac mounted on an O-ring gantry, equipped with a dual-layer stacked MLC with an effective shaping capability of 5mm at iso centre.

Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Introduction

Epiqa is a program that utilises the GLAaS algorithm to derive absolute dose maps from images acquired with amorphous silicon portal imager. To date, the GLAaS algorithm has proved reliable in pre-treatment patient plan verification for standard C-arm linacs (MedPhys 2006). The purpose of this study was to verify the application of the GLAaS principles to a new delivery system, Varian Halcyon, a 6MV FFF linac mounted on an O-ring gantry, equipped with a dual-layer stacked MLC with an effective shaping capability of 5mm at iso centre.

Materials and Methods

The Epiqa configuration requires a primary and a transmitted dose calibration at a certain depth; this dosimetric data was collected at dmax at three institutes to be correlated with the Halcyon digital megavoltage imager (DMI) signal. The satisfactory modelling of the DMI dose response allowed for pre-treatment QA verifications in all the centres. For three different sites (prostate, head-and-neck and breast), each centre pooled 5 patients from its own database to be acquired with DMI and other QA devices locally available (Arc CHECK, MapCHECK, ion chamber point dose). For all centres, DMI images were compared to TPS dose water matrices with GLAaS algorithm and to predicted fluencies with Varian Portal Dosimetry (VPD).

Results

Adapting the GLAaS principles to Halcyon technology, it was possible to conveniently model the DMI dose response. Overall, pre-treatment QA results were fully satisfactory, with differences in terms of specific results dependant on the devices used. In the analysis of DMI images compared to predicted (VPD) and calculated (GLAaS) doses, the gamma agreement index (GAI) values were greater for VPD than for GLAaS (e.g. GAI for 3%-3mm: global VPD = 99.9±0.2% vs GLAaS = 99.1±0.9%, local VPD = 99.2±0.7% vs GLAaS = 94.2±4.1%).

Conclusion

Satisfactory results with all devices confirmed the robustness of both IMRT and VMAT delivery with Halcyon. The extension of GLAaS to Halcyon offers the opportunity to easily set-up a flexible and reliable verification system, allowing a direct yet independent comparison between EPID measurements and TPS water dose maps.

Keywords: Halcyon, GLAaS, Varian Portal Dosimetry.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Going from the Varian Unique to the Varian Halcyon (2.0): A Practical Planning Comparison

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Introduction
The aim of this study is to investigate the differences in the clinical treatment planning workflow and plan outcomes between the Varian Unique and Varian Halcyon (2.0) linacs.

Materials and Methods
A literature search was performed to compare the design features of the Unique and Halcyon linacs with specific focus on the impact of these features on treatment planning choices. The investigation focused on three clinical test cases: (1) prostate, (2) CA cervix, and (3) emergency spinal-cord compression. Analysis of plan quality and treatment delivery workflow was done in terms of positioning strategy, ICRU83 metrics and QUANTEC.

Results
The imaging strategies for the Halcyon and Unique differed for all cases with the Unique using an offline strategy and the Halcyon requiring an online strategy.

Test case 1: Single isocentre VMAT plans were selected as best treatment option for both linacs. Similar target coverage and OAR toxicity was observed for both unit’s treatment plans.

Test case 2: A multi-isosingle setup VMAT treatment plan was required for the Halcyon treatment plan to compensate for the smaller maximum field-size and large treatment volume, compared to the single isocentre VMAT plan that was possible on the Unique due to the larger field size. kV CBCT was employed for the daily imaging strategy for the Halcyon, positioned midway between the two isocentres. Treatment delivery is still done as a single patient setup with automatic repositioning of the patient for the two isocentres.

Test case 3: The unplanned treatment mode (UTM) with manual monitor unit calculation was used as treatment strategy for the Unique. The Halcyon is not capable of delivering unplanned treatments and a full Eclipse treatment plan including patient specific quality assurance is required.

Conclusion
It can be concluded that distinct differences exist in the clinical treatment planning work flow between the Varian Unique and Varian Halcyon treatment units. Each unit has advantages and disadvantages in different scenarios. Both the Unique and Halcyon units can produce high quality plans and allow for efficient treatment delivery.

Keywords: Halcyon; Unique; treatment planning.
A Retrospective Quantitative Study of the Homogeneity and Conformity Indexes for XiO and Eclipse TPS approved plans

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Introduction
In radiotherapy treatment, the main objective is to deliver a therapeutic dose to a tumour whilst minimizing dose to critical organs at risk (OAR). This objective is met by optimizing: Planning target volume (PTV) conformity with regards to prescribed dose, the dose homogeneity within the PTV and dose to the OARs. In the achievement of the objectives, the dose volume histogram (DVH) is the most powerful tool that can be used for this purpose.

Aim
To do a homogeneity and conformity index retrospective study of approved treatment plans in our department. This was done for XiO 3 dimensional conformal radiotherapy (3D CRT) plans on ELEKTA linacs and Eclipse Rapid Arc plans on newly installed Halcyon 2.0. This was done with the goal of having more optimized plans especially for our Eclipse plans.

Materials and Methods
Eclipse TPS and XiO TPS plans, evaluated with ICRU83 and Radiation Therapy Oncology Group (RTOG) recommended equations.

Results
For the Eclipse plans their RTOG component; HI averaged at 1.13 (Ideal = 1) with a standard deviation of 0.02, and the CI having an average of 0.95. ICRU83 component; HI averaged at 0.09 (Ideal = 0) with a standard deviation of 0.05, with the CI having an average of 0.95 and standard deviation of 0. For XiO plans their RTOG component; HI averaged at 1.11 with a standard deviation of 0.02, and the CI having an average of 0.95 and standard deviation of 0. ICRU83 component; HI averaged at 0.12 with a standard deviation of 0.1, with the CI having an average of 0.95 and standard deviation of 0.

Conclusion
The above results formed a basis as reference to optimizing plans and evaluating plans with these indices can help in analysing plan quality along with the normal plan checks.

Keywords: Treatment Planning, Homogeneity Index, Conformity Index.
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Determining the Planning Target Volume Margin for Head and Neck Radiotherapy Treatments using Portal Imaging

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Introduction
The most crucial factor to take into consideration when determining Planning Target Volume (PTV) margins is the geometrical uncertainties. These uncertainties are a combination of systematic and random errors which can occur during patient setup as well as during treatment. These uncertainties need to be limited as much as possible to prevent any overdose to critical structures. However, making the limits too low can result in under dosing of the tumour volume. For this study, an electronic portal imaging device (EPID) was used to determine shifts in the lateral, longitudinal and vertical directions for head and neck tumours.

Aim
The aim of this study is to determine PTV margins for head and neck (H & N) target volumes for 3D conformal therapy (3D CRT).

Materials and Methods
Quantitative analysis was done on the portal images of 40 H & N cancer patients treated on an Elekta Precise at Tygerberg Hospital. All patients treated between 21/05/2018 to 31/01/2019 were included in the study. Images were analysed for the first three fractions (daily) and thereafter weekly. All patients received all fractions as scheduled and there were no treatment interruptions. The shifts were recorded in an Excel spreadsheet and statistical analysis, consisting of random and systematic error calculations, was performed on the dataset.

Results
For the daily fractions, the margins for the three directions are as follow: 0.39 cm for lateral, 0.45 cm for longitudinal and 0.49 cm for the vertical direction. For the weekly fractions, the calculated margins are 0.38 cm for lateral, 0.48 cm for longitudinal and 0.43 cm for the vertical direction.

Conclusion
These results confirm the validity of the current treatment margins of 0.5 cm in each direction for 3D CRT.

Keywords: EPID; PTV; Margins; Head and Neck radiotherapy.
Are our Doses Correct? Dose Calculation Accuracy of Treatment Planning Systems in the Presence of the Prosthesis

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Introduction

A significant number of patients in radiation therapy patients are treated with prosthesis. Most Radiation Therapists/Dosimetrist minimize treatment planning inaccuracies by avoiding radiation beams to transit through the prosthesis but sometimes the beam often exits through the prosthesis, in cases when the patient has a double-prosthesis or other complicated implants. The high density and atomic number of these prostheses for patients undergoing radiotherapy poses some challenge on CT scans and also the ability to accurately calculate dose from TPS.

Material and Methods

In Steve Biko Hospital, a few referrals with prosthesis implants were sent for planning with the Monaco TPS and for treatment with radiation. Challenges with CT, Planning and plan verifications were analysed for these patients. Capabilities of TPS for planning and calculating accurate doses were explored. Prosthesis was also molded inside a phantom and the dose at several points within the phantom was computed using both chamber and RPLD’s.

Results

Treatment plans calculated with and without inhomogeneity corrections were evaluated. Treatment plans calculated with different algorithm were also compared and doses analysed and measured. The results of the study indicate there are significant dose calculation and dose delivery consideration that must be taken into account when attending to patient with different prosthesis.

Keywords: Prosthesis; RPLD-Radio photo luminescent dosimeter.
Nano Dosimetric Track Analysis in a Spread-Out Proton Bragg Peak

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Introduction

A key finding of the BioQuaRT project was a simple relation between radiobiological cross sections for cell in activation by ion beams and nanodosimetric characteristics of the particle track structure of these beams. Options for translating nanodosimetric information at the voxel level have also been investigated. This work carries these approaches further by using nanodosimetric track structure analysis for estimating RBE variation in a clinical spread-out Bragg peak (SOBP) of protons.

Materials and Method

For 100 MeV protons entering a water phantom, the track structure has been simulated using Geant 4-DNA for a number of positions along the pristine Bragg peak. Ionization cluster size distributions (ICSDs) were scored for targets of size corresponding to a 10 base-pairs segment of DNA was obtained for a set of radial distances from the proton trajectory and positions along the proton path. The functional dependence of nanodosimetric parameters on radial distance was analyzed using simple model functions and afterwards convolved with weighted distributions of the range taken from literature to construct a SOBP.

Results

For the track core, the radial dependence of ICSDs could be reproduced assuming a superposition of a term proportional to the chord of the proton track and a contribution of electrons growing with the square of the radial distance. In the penumbra region, an inverse power law provided good fits in the entrance region while an exponential dependence was found within the last few tens of μm of the track. Integrating the radial dependence of the nanodosimetric cumulative probabilities for at least two or more ionizations in the target gave a quantity that an increase over the SOBP that is in qualitative agreement with observations of enhanced relative biological effectiveness (RBE) in this region.

Conclusions

These encouraging preliminary results show the potential of using nanodosimetric track characteristics for predicting the variation of RBE for lethal lesions in cells in clinical situations. In ongoing further analysis, the influence of range straggling of the protons and of a non-homogeneous spatial distribution of targets (DNA is only found within cell nuclei) and of the influence of on the outcome of the nanodosimetric prediction will be investigated.

Keywords: BioQuaRT; RBE; Geant4-DNA.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Technical Feasibility of [18F]-FET and [18F]-FAZAPET Guided Radiotherapy in a F98 Glioblastoma Rat Model

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Introduction
Glioblastoma (GB) is the most common primary malignant brain tumor. Standard medical treatment consists of a maximal safe surgical resection, subsequently radiation therapy (RT) and chemotherapy with temozolomide (TMZ). An accurate definition of the tumour volume is of utmost importance for guiding RT. In this project, we investigated the feasibility and treatment response of sub volume boosting to a PET-defined tumour part.

Materials and Methods
F98 GB cells inoculated in the rat brain were imaged using T2-and contrast-enhanced T1-weighted (T1w) MRI. A dose of 20 Gy (5 × 5 mm²) was delivered to the target volume delineated based on T1w MRI for three treatment groups. Two of those treatment groups received an additional radiation boost of 5 Gy (1 × 1 mm²) delivered to the region either with maximum [18F]-FET or [18F]-FAZAPET tracer uptake, respectively. Treatment planning CT was obtained on the small animal radiation research platform (SARRP) and images were fused. All therapy groups received intra-peritoneal (IP) injections of TMZ. Finally, a control group received no RT and only control IP injections. The average, minimum and maximum dose, as well as the D90-, D50- and D2-values were calculated for nine rats using both RT plans. To evaluate response to therapy, follow-up tumour volumes were delineated based on T1w MRI.

Results
When comparing the dose volume histograms, a significant difference was found exclusively between the D2-values. A significant difference in tumor growth was only found between active therapy and sham therapy respectively, while no significant differences were found when comparing the three treatment groups (p-value 0.082–1 for [18F]-FET; 0.327-1 for [18F]-FAZAPET).

Conclusion
In this study, we showed the feasibility of PET guided sub-volume boosting of F98 glioblastoma in rats. No evidence was found for a beneficial effect regarding tumour response. However, improvements for dose targeting in rodents and studies investigating new targeted drugs for GB treatment are mandatory.

Keywords: Glioblastoma; Positron emission tomography guided radiotherapy; Preclinical; Radiotherapy.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Changes in Metabolic Activity of Cancer and Normal Cell Lines after X-ray Irradiation and Inhibitor Treatment

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Introduction

Cell metabolism supplies essential components for repair, survival and proliferation. Metabolic reprogramming is used by cancer cells to adapt to their microenvironment and support processes which require high metabolic activity. Therefore, the development of novel therapeutic strategies which target cell metabolism may provide therapeutic potential. This study, thus, investigates the effect of X-ray irradiation and inhibitor therapy on cell metabolic activity.

Materials and Methods

A human lung cancer cell line (A549), a normal lung cell line (L132), and a cervical cancer cell line (HeLa) were assessed. Cells were seeded in a 96-well plate, after an overnight incubation, a dose of 2 Gy of X-rays or the equivalent concentration at which 50% cell kill occurred (EC50) of an EGFR inhibitor (AG-1478), PI3K/m TOR inhibitor (NVP-BEZ235) or Bcl-2 inhibitor (ABT-263), or a combination of inhibitor and 2 Gy of X-rays was administered to these cells. An MTT assay was performed 30 minutes and 2 hours after treatment, to measure metabolic activity.

Result

The single treatment of 2 Gy enhanced metabolic activity 30 minutes after treatment and reduced metabolic activity 2 hours after treatment for both lung cell lines. The cervical cancer cell line (HeLa) showed a decrease in metabolic activity, 30 minutes after 2 Gy of X-ray irradiation and an enhancement in metabolic activity 2 hours after treatment. The combination treatment appeared to increase metabolic activity of the A549 and L132 cell lines for both time points, except when treated with an NVP-BEZ235/ABT-263 cocktail and 2 Gy. Metabolic activity of HeLa cells treated with an inhibitor cocktail and 2 Gy appeared to have a similar response as HeLa cells that had been singly treated with inhibitors or X-rays.

Conclusion

These data suggest that single X-ray irradiation, EGFR and PI3K/m TOR inhibitor and Bcl-2 inhibitor therapy, as well as, the combination of these treatment modalities may have an impact on cancer and normal cell metabolic activity. Targeting the metabolic pathway may have some therapeutic benefit.

Keywords: Inhibitor cocktails; Metabolic activity; Therapeutic benefit.

https://globalmedicalphysics.org/
Radio Frequency Field Exposure Enhances In-Vitro Cellular Radio Sensitivity

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Introduction
There are many challenges encountered in cancer therapy, the major ones being tumour resistance to treatment and normal tissue toxicity. Melanoma, sarcoma and prostate cancer are some of the superficial cancers that are best treated with hypo fractionation (i.e. use of large fractional doses of radiation). Hypo fractionation, however, leads to high normal tissue toxicity which the patient may not easily recover from. There is an urgent need to develop non-invasive methods, to sensitise cancer cells (or tumours) to therapeutic doses of ionising with reduced normal tissue toxicity or side effects. Here, a radio frequency field (RFF) was evaluated for its potential for sensitising tumour cells to radiation therapy.

Materials and Methods
Four cell lines: DU145 (prostate cancer cells), MeWo (melanoma cells), Be11 (melanoma cells) and L132 (human lung fibroblasts), were used. Exponentially growing cell cultures were trypsinised into single-cell suspensions and seeded in varying numbers for colony forming and micronucleus assays. The cells were exposed to either 2 or 6 Gy of X-rays before or after a 1000-Hz modulated RFF exposure and incubated for the prescribed times depending on assay. The surviving fractions and micro nuclei frequencies were then calculated and used to determine the effect of RFF on radiosensitivity.

Results
Exposure to the RFF prior to or after X-ray treatment led to higher radiosensitivity. In all cell lines, there was higher sensitisation at 6 Gy compared to 2 Gy. RFF exposure led to increased micro nuclei frequencies.

Conclusion
These findings suggest that radio frequency fields could potentially be used to enhance treatment outcome in hypo fractionated radiotherapy.

Keywords: Radio frequency field; hypo fractionated radiotherapy; radio sensitisation.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Dose-and Image Optimization in Computed Tomography Chest- and Brain-examinations for Adult Patients using the Taguchi Analysis

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Introduction

Since the clinical use of a CT scanner has considerably increased over the last few years, the aim for this study was to optimize a CT protocol by varying parameters such as the kVp-setting, the mA-setting, the level of noise and the type of reconstruction filters used. The optimization should still be in terms of the ALARA-principle. The output factors included noise, contrast-to-noise ratio and dose per scan.

Materials and Methods

The study was carried out on the GEDiscovery TMLight speed VCT, 64-slice CT scanner. An RSD OpaquePIXY phantom was used to perform the scans to find a balance between image quality and dose. The optimization method used is the TaguchiL9 orthogonal array analysis that resulted in a series of nine sets of experimental scans. The images obtained were evaluated objectively and statistically using the RadiAnt program. The effective dose was calculated using the ImPACT-program and the figure of merits was calculated using Minitab19.

Results

For the chest-protocol, the optimal experiment for noise and CNR is 5 and 3 respectively. According to the diagnostic reference level for a chest CT scan, the dose is 30 mSv. Experiment 3 had an effective dose of 35 mSv. The highest effective dose was 96 mSv and it was due to experiment 10. For the brain-protocol, the optimal experiment for noise and CNR is 7 and 3 respectively. The maximum dose resulted from experiment 9 and the minimum dose, from experiment 1.

Conclusion

For the chest-protocol, the kVp-setting may be reduced from 120 kVp to 100 kVp. The other parameters will remain the same as the nominal settings. For the brain-protocol, the parameters used clinically are already optimized for both image quality and dose. It is recommended that a figure of merit in terms of CNR is more efficient than for noise. It is also advisable to rather not use the level of noise and the type of reconstruction filters in terms of optimization for image quality.

Keywords: Taguchi analysis; CT; Optimization.

https://globalmedicalphysics.org/
Towards Clinically Robust Cardiac Diffusion MRI using Prospective Respiratory Motion Correction

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Introduction

Previously, a prospective respiratory motion correction control system was used to perform in-vivo slice tracking of the heart. Cardiovascular diffusion tensor imaging (cDTI) is an emerging technique that may have clinical utility in assessing and quantifying microstructural changes in the heart. Its utility is hampered by long scan times particularly due to multiple, long breath-holds presenting a significant challenge to patients. The ability to perform cDTI acquisitions under free-breathing conditions may improve its clinical utility. The motion correction control system was implemented and tested in a second-order motion compensated spin echo (M2SE) diffusion sequence.

Methods

Four volunteers were scanned in a 3-Tesla Siemens Prisma MRI scanner. The M2SE sequence was coupled with four respiratory compensation techniques: multiple breath-holds, standard respiratory gating, and standard respiratory navigators with slice tracking, and the prospective motion correction control system to perform slice tracking. Four b-values with six diffusion directions were collected: 350, 450, 550, and 650 s/mm², repeated eight times. An in-house MATLAB post-processing tool was used to analyse the images. Images were registered together using simple, rigid transformations to reduce motion effects. The apparent diffusion coefficient (ADC) and fractional anisotropy (FA) were calculated, using 350 s/mm² as the reference b-value to reduce perfusion effects. These results were compared using a linear mixed-effect model to account for multiple measurements per subject; inter-subject variability was quantified using the standard deviations.

Results

The lengths of the acquisitions were as follows: breath-hold (8-15 minutes); gated (7-12 minutes); both slice tracking sequences (3-6 minutes). The respiratory efficiency of the gated acquisition was 40-80% while both slice tracking acquisitions were 100%. The results of the linear mixed-effect model showed no significant differences between the respiratory compensation techniques. The ADC and FA inter-subject variability was low for all techniques. The standard slice tracking (0.06-0.11) and the control system slice tracking (0.09-0.10) sequences had lower variation in ADC values than the breath-hold (0.08-0.84) and gated techniques (0.08-0.25).

Conclusion

The prospective respiratory motion correction control system may be useful in improving the viability of cDTI in a clinical setting by allowing acquisitions to take place under free-breathing conditions.

Keywords: Magnetic resonance imaging; cardiovascular; new techniques; motion correction.

https://globalmedicalphysics.org/
Usability of the U-QA Phantom for kV CBCT Image QC on the Varian Halcyon (2.0) Linac

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Introduction

Halcyon (2.0) is Varian’s newest linear accelerator (linac) platform designed for image guided radiotherapy (IGRT). The unit houses an onboard imager kilo voltage (kV) imaging system with cone beam computed tomography (CBCT) capability. Routine image quality control (QC) is needed to evaluate system image quality according to the imaging metrics as stipulated in the South African Standards for Quality Assurance in Radiotherapy (SASQART) document on IGRT. For CBCT commissioning and annual testing the recommended image quality tests are density resolution, spatial linearity, image uniformity, high resolution and low contrast resolution. This study aims to investigate the usability of the universal quality assurance (U-QA) image quality phantom for routine kV CBCT IGRT QC on the Halcyon (2.0) linac.

Materials and Methods

Image quality tests were performed for the head, thorax and pelvis kV CBCT imaging protocols on the Halcyon (2.0) linac using the U-QA phantom. Only the conventional CBCT reconstruction using the Feldkamp-Davis-Kress (FDK) algorithm was evaluated. The image quality parameters from SASQART were evaluated using the Phantom Scan software. Additionally, circular geometry, image noise and standard signal could also be measured with the U-QA phantom. This was repeated for ten repositioning set-ups of the phantom.

Results

The U-QA phantom package produced reproducible results for all the imaging protocols evaluated, within the acceptable SASQART tolerance limits. The phantom could evaluate all the image QC required by SASQART. Moreover, the phantom was also suitable to evaluate set-up errors and calculated couch correction movements from image matching.

Conclusion

It may be concluded that the U-QA phantom, with the accompanying data-analysis software and user’s manual, offers an acceptable phantom solution for routine consistency kV CBCT IGRT QC on the Halcyon (2.0) linac in accordance with the recommendations from SASQART.

Keywords: kV CBCT; image quality; phantom; quality control.
Evaluation of Eclipse Pre-configured Beam Data for Newly Installed Halcyon

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Introduction
In the commissioning of a Linear accelerator for clinical use, physicists are faced with challenges which include the need for precision, various testing tools, data validation and time constraints. Since data will be used as reference and treatment planning system (TPS) data, the data collected needs to be of the highest quality. With the advent of new technology and type of linear accelerators, the importance of beam data collection for use in the TPS has become more and more important in radiotherapy. The halcyon beam data comes pre-configured in the Eclipse TPS, which this gave rise to the question what can be tested and what happens to the reference data part for the linear accelerator commissioning.

Aim
To acquire reference data (Percentage Depth Doses (PDD’s), Profiles, Output Factor) of the newly installed Varian Halcyon linear accelerator in Tygerberg Hospital. Compare this data with pre-configured Eclipse data.

Materials and Methods
IBA blue phantom2 scanning tank, IBACC04 scanning ionization chamber, PTW semi flex ionization chamber and IBA Omnipro accept 7.4b.

Results
Analysis of both PDD’s and Profiles was analysed with done using a 1-D Gamma analysis software called Scan Dose Match, which allows for the Gamma analysis of the pre-configured PDD’s and profiles to the measured data. Profiles at 90cm SSD for depths Dmax, 5, 10, 20 and 30 cm for varying field sizes (2 x 2 to 28 x 28) were found to have a Gamma index ≤ 0.6 for a 2%/2mm setting. For PDD’s at 90 cm SSD the Gamma index was ≤ 0.3 for varying field sizes with a 2%/2 mm setting. Output Factors at 95 cm SSD and 5cm Depth for varying field sizes had a mean percentage difference of 0.2%.

Conclusion
The pre-configured beam data model for the Halcyon was found to be in good agreement with our reference measured data.

Keywords: Halcyon; Eclipse; Commissioning.
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Varian Halcyon Treatment Delivery System: From Physics Equipment to Clinical Commissioning

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Introduction
With the first Halcyon installation in South Africa, Yenzakahle was requested to advise on the purchase of physics equipment based on the available information at the time. Yenzakahle was responsible for the commissioning process of the Varian Halcyon Treatment Delivery system including Initial Product Acceptance testing, SASQART tests and ‘in house’ testing, using the PTW Beamscan, PTW Verisoft with Octavius 2D system and the Epiqa EPID based system and the Varian Portal Dosimetry system.

Materials and Methods
Following many discussions and communications with people from Varian, MD Anderson as well as online research, a list of needed physics equipment was drawn up. Following the manufacturer specific testing outlined in the Initial Product Acceptance document C, the South African SASQART regulation testing and the AAPM MPPG 5a document in part combined with a series of initial patient measurements using both Verisoft and the Octavius system, the Halcyon Treatment Delivery System was commissioned for clinical use.

Results
The Halcyon Treatment Delivery system was commissioned and put into clinical routine. A beam model verification was concluded, and patient specific measurements were all within acceptable agreement for clinical use of the Halcyon Treatment Delivery System.

Keywords: Halcyon; Beam scan; Commissioning.
Beam Data and Treatment Planning System Validation

Measurements for Commissioning a Newly Installed Halcyon LINAC at Groote Schuur Hospital

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Introduction

Groote Schuur Hospital has recently installed a new Varian Halcyon linear accelerator (linac) in its Radiotherapy Department. A Halcyon linac has specialized capabilities, including VMAT and kV cone beam CT, for advanced treatment techniques to give modern high quality of care and operational excellence. It is a general requirement that following an installation of any radiotherapy machine, commissioning tests should follow before the machine can be used clinically. Commissioning a linac involves a series of tasks including, but not limited to, acquiring radiation beam data required for treatment and entering this data into a treatment planning system (TPS). However, the Halcyon’s beam data is already preconfigured and modelled fully in Eclipse, hence, in this work, we validate the preinstalled beam data and treatment planning system model.

Materials and Methods

Percentage depth doses, profiles and diagonals were measured in a PTWBEAMSCAN™ 3D water phantom with 2 x PTW Semifl x 0.125 cc (one as reference) and a micro Diamond detector using the PTW software. Analysis of the beam data was performed with Scan Dose Match software. The CIRS phantom was scanned and planned for clinical commissioning tests according to the IAEA TECDOC-1583. The measurements were done with a PTW-electrometer and 0.6 cc Farmerionisation Chamber.

Results

The measured scan data showed 100% agreement with reference data when a 1%/1 mm gamma analysis criterion was applied for both detectors. Discrepancies were only observed in the cross plane profiles measured with the micro Diamond detector for the same gamma criterion. However, a 100% agreement was achieved when a 1.5%/2 mm gamma criterion was applied. Spot checks of output factors at different field sizes (FSs) were found to be <0.5% for the Semi flex detector. The Micro diamond detector also achieved a < 0.5% deviation with higher deviations of up to 1.2% for smaller FSs. Clinical commissioning tests for the TPS that apply to the Halcyon compared well with the predicted TPS dose to within 3% deviation, with exceptions observed for measurements in lung.

Conclusion

There exists a good correlation between the measured data and the preconfigured TPS data which implies that this part of commissioning tests were successful.

Keywords: Halcyon; Commissioning; TPS.
Biomarker Investigation on the Health Effects of CT X-Ray Exposure in Children: A Plea to “Image Gently”

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Introduction
The optimization and justification of CT imaging is receiving increasing attention, particularly for children, who are more sensitive to the effects of ionizing radiation compared to adults. Therefore, it is crucial that one minimizes the potential risks, while maximizing the potential benefits to each individual patient. The importance of dose optimization was investigated in a biomarker study, in which the γ-H2AX foci assay was used as biomarker for radiation-induced double strand breaks in combination with a patient-specific Monte Carlo dose simulation.

Materials and Methods
In this multi centre study, 51 paediatric patients (mean age, 3.8 years) were included. Patients underwent a CT abdomen (10) or CT chest (41) in five Belgian radiology departments using state-of-the-art CT instrumentation and protocols. Blood samples were taken before and after the CT procedure and γ-H2AX foci were determined in peripheral blood T-lymphocytes. Patient-specific organ and tissue doses were calculated using Impact MC 1.3.1 Monte Carlo software. Blood doses were calculated as a weighted sum of doses to lungs, heart, liver and remainder.

Results
The use of state-of-the-art low dose equipment and specific paediatric protocols resulted in very low CTDI vol (1.85 mGy for chest CT; 2.80 mGy for abdomen CT) and DLP values (24.80 mGycm for chest CT; 100 mGycm for abdomen CT). As a result, the simulated average blood dose was only 1.35 mGy (range: 0.15-8.85 mGy). However, this still induced a small, but significant increase in DNADSBs (0.13γ-H2AX foci/cell). Substantial differences in dose-sparing equipment and imaging protocols for children resulted in differences in patient doses and corresponding DNA damage. The study illustrated a clear correlation between dose sparing techniques and induced DNA damage for the different participating hospitals.

Conclusion
Even when low dose equipment and specific protocols were used, CT X-rays induce DNA-damage in children. The present study emphasizes the need for justification and dose optimization in paediatric radiology. Since this study was conducted in Europe, it is advisable to repeat this study on a South African population, with a biomarker that might be more relevant to secondary cancer risks, such as chromosomal aberrations.

Keywords: X-ray computed tomography; Double-strand DNA breaks; Radiobiology; Gamma H2AX foci; Paediatrics.
Precision Medicine: Radiogenomics and the Development of Individualized Radiotherapy for Cancer Patients in South Africa

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Introduction
Approximately 50% of all cancer patient will receive radiotherapy as part of their treatment. The maximum radiation dose that can be delivered with radiation therapy is limited by the tolerance of normal healthy tissue that inevitably gets exposed in the treatment field. Radiation therapy related toxicity has been shown to have variability in onset and severity depending on the individual and 80% of the variability can be attributed to genetic factors. Precision medicine aims to customize treatment to the genetic profile of the individual. Although there are studies reporting associations between individual genes as well as gene panels, there are currently no robustly validated radiogenomic biomarkers that are routinely used in clinical practice. In addition, most of these studies are performed on Caucasian cancer populations and the results might not be applicable to our unique African populations. Genetic associations must be replicated in validation studies in both the same-and other ethnicities to strengthen their predictive value for use in clinical practice.

Materials and Methods
DNA samples in the form of buccal swabs are collected from head-and neck cancer patients. The association between genetic factors and the onset of early and/or late toxicities following radiotherapy will be recorded using well-established toxicity scales. Mass array panels of single nucleotide polymorphisms (SNPs) for radiotherapy are developed and validated for genotyping Confounding factors such as treatment related factors (surgery, dosimetric parameters, delivery technique, fractionation scheme and other concomitant treatments), age, smoking status and other co-morbidities that may influence the toxicity outcomes will be captured and taken into consideration in the association analysis.

Results
Important genomics data will be obtained for relevant SNPs associated with radiotherapy-induced toxicities. The data will be used to provide evidence of association between genetic variants and toxicity in order to validate previously established genomic biomarkers for African populations.

Conclusion
There is a great potential to use the genetic profile of cancer patients to individualize treatment and reduce the number of patients suffering with the acute-and long-term consequences of radiotherapy.

Keywords: Genetic polymorphisms; biomarker; radiotherapy; translational research; head and neck cancer patients.
Evaluation of Right Breast Radiotherapy for Liver Doses

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Introduction

Our goal is to investigate the three dimensional conformal radiotherapy (3D CRT), step-shoot intensity-modulated radiotherapy (s-IMRT), dynamic intensity modulated radiotherapy (d-IMRT) and volumetric modulated arc therapy (VMAT) treatment plans of right breast radiotherapy for liver doses.

Materials and Methods

A total of 30 right breast cancer patients with T1N0M0 stages were planned using 3D CRT, s-IMRT, d-IMRT and VMAT technique. Monte Carlo (for s-IMRT, d-IMRT and VMAT) and Collapsed Cone (for 3D CRT) algorithms were used on Monaco treatment planning system (TPS) (v5.11) to prepare the treatment plans. Four treatment plans were generated for each patient: Firstly, 3D CRT, 6 MV energy including internal (50°-60°) and external (230°-240°) tangential fields. Secondly, s-IMRT and d-IMRT with 6 MV energy including 9-11 coplanar fields; thirdly, VMAT with and without flattening filter 6 MV photon beams including 360 degree total gantry rotation. 30 breast cancer patients divided into 3 groups depending on breast size. The mean PTV sizes in A-groups (14.30cm–15.76cm), B-groups (15.77cm–17.22cm) and C-groups (17.23cm–18.68cm). All plans were examined in respect to conformity index (CI), homogeneity index (HI), liver volume doses and breast size at mid-clavicular point.

Results

A group showed a better HI% 5 with VMAT. The mean dose and 3D CRT plans in group A showed the lowest value for %V5 (3.98 ± 3.29), %V10 (2.71 ± 2.60), %V20 (1.80 ± 2.06) and %V40 (0.63 ± 1.12) in the liver. The Liver max dose, d-IMRT (33.25 ± 10.41) Gy and VMAT (33.24 ± 10.63) Gy plans in group A showed the lowest value. In low dose regions VMAT plans were founded significantly higher values.

Conclusion

For right-sided breast cancer radiotherapy after breast-conserving surgery, the VMAT, the s-IMRT and the d-IMRT plans had better CI and HI than the 3D-CRT plans. VMAT demonstrated great HI but an increased low-dose volume outside the PTV should be of concern. Our studies showed that four different plan technique and PTV size for the right breast were effective on the dose received by the liver. We found that if the PTV size is more than 15.77 cm in the middle clavicular line, the liver should be contoured.

Keywords: Breast Cancer; Liver Dose; Volumetric Arc Therapy.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Verification of LINAC Log Files with Commercial QA Systems: Non-Clinical Beams

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Introduction

Advanced radiotherapy techniques such as Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) are used as standard treatment techniques for many clinical indications. Patient-specific Quality Assurance (QA) to verify these treatments is critical, and must be performed accurately for every patient. Current detector-based QA is costly and time-consuming, and most systems do not allow for real-time verification. Linac log files (LF) can provide a suitable alternative. The aim of this study is to verify an in-house developed LF-based treatment plan verification solution for non-clinical beams.

Materials and Methods

Fifteen static and dynamic non-clinical beams covering a range of MLC-, Gantry-and dose-rate variation combinations, were delivered on an Elekta™ Synergy® Linac with 160-leaf Agility® MLC. Three different commercial detector systems, namely IBAMatrixX™, PTW Octavius™, and IBADolphin™, were used to verify the treatments while Linac LFs were simultaneously recorded. In-house codes were developed in IDL™ to subsequently convert LFs to DICOM RT plan format for recalculation on the Monte Carlo based system, SciMoCa™. Comparisons between planned and recalculated dose distributions were done independently in each system, and the results correlated.

Results

The detector QA results for each commercial system correlated very well with the corresponding LF results for all test beams. Dose differences found in LF calculations were confirmed by the corresponding detector system. A high degree of agreement was also observed between all detectors and LFs. Various technical considerations and caveats were identified when using LF-data.

Conclusion

The in-house LF-based solution was successfully verified with commercial detectors, and compared favourably to the planned doses as well as the detectors’ distributions. The LF plan verification tool can be used in non-clinical cases as substitute to detector measurements, provided linac machine QA is performed in combination.

Keywords: Arc therapy; Log files; QA.
Inhibitions of PARP-I by ABT888 can Potentially Cause Reduction in Colony Size of Lung Cancer Cells

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Introduction
Lung cancer remains one of the most frequent causes of cancer deaths in both males and females. It can evolve from smoking, occupational exposures, infections, change in lifestyle, and environmental pollutants. The limitations of conventional therapeutic strategies, coupled with acquired and/or inherent tumour resistance, have resulted in the need for novel treatment strategy. New therapeutic strategies have been focused on the activation of programmed cell death, through inhibition of B cell lymphoma-2 (BCL-2) and the control of DNA repair mechanism by blocking the activity of poly [ADP-ribose] polymerase 1 (PARP-1) in support of radiotherapy. The overall goal of this study was to investigate the impact of silencing DNA breaks repair, via inhibitor of PARP-1, on colony forming capacity of human lung cell lines.

Materials and Methods
A human lung cancer cell line (A549) and apparently normal cell line (L132) were treated with a PARP-1 inhibitor of (ABT-888), at concentrations ranging from 0 to 14 days to form colonies. The colonies were then fixed, stained, and counted for determination of cell surviving fractions. Photographs of colonies were also taken for subsequent determination of colony size.

Results
Based on clonogenic survival, no significant toxicity was observed in either cell line. However, a marked inhibitor concentration-dependent reduction in colony size was observed in the cancer cell line (A549). No treatment-induced effect on colony size was observed in the apparently normal cell line (L132).

Conclusion
These data suggest that inhibition of PARP-1 using ABT-888 may cause reduction in tumour size, with no apparent effect on normal tissue.

Keywords: PARP-1 inhibition; ABT-888; Lung cancer.
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Concomitant Targeting of PI3K, mTOR and AR Exhibits Strong Synergism in Human Prostate Cell Lines

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Introduction

Although chemotherapy drugs have entered numerous PCa clinical trials with great results in improving patient survival, tumour resistance and systemic toxicity remain key challenges. Single agent use is very limiting, as large doses are often required for tumour control and leads to elevated systemic toxicity. Concurrent use of multiple agents at low doses is, therefore, an ideal modality. Epidermal growth factor receptor (EGFR), Phosphoinositide 3-kinases (PI3K), mammalian target of rapamycin (mTOR) and androgen receptor (AR) are survival proteins implicated in PCa progression. Concomitant targeting of these proteins with cocktails of specific inhibitors might yield optimum therapeutic benefit with minimal toxicity.

Materials and Methods

In this study, the modes of interaction of the dual inhibitor of PI3K and mTOR (NVP-BEZ235), EGRF inhibitor (AG-1478), and AR inhibitor (MDV3100) in in-vitro cultures of four human prostate cell lines (DU145, LNCaP, BPH-1 and 1542N) were evaluated, using clonogenic cell survival. For this, the following cocktails were used: Cocktail 1 (AG-1478 and NVP-BEZ235), Cocktail 2 (NVP-BEZ235 and MDV3100), and Cocktail 3 (MDV3100 and AG-1478). Components of cocktails were used at equivalent concentrations for 50% cell killing. Combination indices (CI) for the cocktails were determined and used as descriptors of inhibitor interaction.

Results

Of the three cocktails, Cocktail 2 showed strong to very strong synergism in all cell lines.

Conclusion

Concurrent inhibition of PI3K/mTOR and AR pathways could potentially be of better therapeutic benefit than cocktails of (AG-1478 and NVP-BEZ235) or (MDV3100 and AG-1478), as the potential benefit of EGFR targeting was found to be limited.

Keywords: Prostate cancer; Inhibitor cocktails; Combination indices.
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Treatment of Uveal Melanoma Using Ruthenium-106 Eye Plaques

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Introduction

Brachytherapy for treating ocular malignancies has been widely used around the world. In South Africa, Strontium 90 eye applicators have been used for the last 30 years for treating Pterygia. The COMSI-125 plaques have been used in the Western Cape and more recently the “Claw” was developed at Groote Schuur Hospital. Ruthenium-106 eye plaques have been in use in Europe since the 1960s, but up until now this technology has not been available in South Africa. In July 2018, the Johannesburg Eye Hospital commissioned 3Ru-106 eye plaques to complement its existing surgical programme.

Materials and Methods

Three eye plaques were purchased with diameters 15.3, 20.2 and 24.8mm. Eckert and Ziegler (Bebig) provide calibration certificates for each plaque containing dose rate and depth dose information. They also provide the coefficients of a third order polynomial fit to the depth dose values. This fitted curve can be quite inaccurate for deeper seated tumours. Accordingly a dose calculation algorithm was developed using exponential interpolation between the depth dose values. This algorithm was incorporated into a custom designed application to calculate dose for Ru-106 eye plaques. The dose calculation methodology was validated by an independent physicist at Bebig and further validated by hand calculations. Further assistance was provided by Clatterbridge Cancer Centre, UK. 16 patients have been treated to date. For each patient the calculated dose was manually checked by a hand calculation using the Bebig polynomial.

Results

The maximum difference between our algorithm and the Bebig was 2.3% and can be attributed to the increasing inaccuracy of the Bebig fit at depth. Patient follow up indicates that both anterior and posterior segment tumours were treated safely and effectively with these plaques. At 6 months review, a marked reduction in tumour thickness was noted and the evolving surrounding chorio retinal scar was seen in treated posterior tumours.

Conclusion

Ru-106 eye plaque treatment for uveal melanoma is a safe and effective treatment. As mall application was developed to simplify dose/time calculations.

Keywords: Uveal melanoma; brachytherapy; eye plaques.
Comparison of Planned and Real-Time In-Vivo Diode Dosimetry during High Dose Rate 192Ir Brachytherapy of Cervical Cancer Using Rectal Semiconductor Probe in Order to be Implemented at Charlotte Maxeke Johannesburg Academic Hospital, Gauteng

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Introduction
In-vivo diode dosimetry is an essential quality assurance method for HDR brachytherapy of cervical cancer. It provides information that contributes to the reduction of errors and discrepancies in dose delivery. Besides considering the operation of the optimization algorithms that can maximise dose uniformity to the target, dose to the rectum can be unacceptably high in some clinical situations. Radiation dose to the rectum should be accurately monitored owing to that it is one of the most sensitive critical organs.

Materials and Methods
A PTW multisoft version 1.3 software (Germany) was used in this study. This treatment unit was controlled and monitored using the multisof operating system located in the control room. The radiation source used was Iridium 192 incorporated in the nuclear HDR unit. A flexible PTW probe type 9112 (PTW, Germany) was used for rectal dose measurement. Prior to every in-vivo rectal dose measurements, the PTW probe was calibrated with Iridium 192 source and built-in electrometer. A PMMA cylindrical after loading phantom, type 9193 (PTW, Germany) also known as Krieger phantom was used for the insertion of the rectal probe for calibration.

Results
The absolute percentage differences between calculated and measured dose ranged from 9% to 40.1%. This corresponded to dose differences ranging from 0.4 Gy to 2.0 Gy. The median percentage differences ranged from 1.5% to 6.4% which corresponded to differences of 2 Gy to 1.6 GY.

Conclusion
Based on this study, the in-vivo diode dosimetry is feasible and can be brought into practice to predict accurately the dose delivered to the rectum during HDR brachytherapy using Iridium 192. It also helps to verify the consistency of the treatment planning system.

Keywords: High dose rate brachytherapy; In-vivo dosimetry; Iridium 192.
Evaluation of Customized Treatment Planning for Image-Guided High-Dose-Rate Brachytherapy for Cervical Cancer

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Introduction
High-dose-rate (HDR) Brachytherapy has been highly adopted in recent years and it has been recommended that the use of MRI imaging is the best practice for cervical Brachytherapy treatment. This approach is not frequently used in South Africa due to the lack of MRI scanner availability; therefore, CT scanning is a more accessible approach. The Single Plan (SP) approach is used widely which involves contouring and treatment planning at the first fraction and then applying the same treatment plan to the remaining fractions. Customized planning (CP) is a widely implemented approach which involves contouring and treatment planning at each fraction. The purpose of this study was to investigate the various differences to Organ at Risk (OAR) doses when CP is used instead of the SP approach.

Materials and Methods
22 CT-based treatment plans were evaluated for 6 patients receiving HDR Cervical brachytherapy prescribed to point A. For each patient approximately 4 treatment fractions were planned with varying prescription sizes. For each fraction the OARs (Bladder and Rectum) were contoured. CP and SP were used for each patient. For the SP approach the first fraction CT scan was adapted for subsequent treatment fractions and dwell times were replicated.

Results
The dose per fraction for each patient to point A and the D2cc to the OARs was obtained. The average dose per fraction during the CP approach to Point A was 6.42Gy, 7.42Gy to the Bladder and 4.84 Gy to the Rectum. For the SP approach the average dose per fraction to Point A was 6.76Gy, 8.21Gy to the Bladder and 5.66Gy to the Rectum.

Conclusion
Dose values for the SP approach were generally higher than for the CP approach. In particular, a significant increase in the total dose to the Rectum (D2cc) from 23.0 to 31.2Gy was observed for one patient. Variation in prescription made it difficult to obtain comparable results amongst patients. Due to lack of statistics a follow up study is required to draw a more accurate conclusion.

Keywords: Cervical Brachytherapy; Organs at Risk; Single Plan (SP); Customized planning (CP).
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

The “Other” Half of the Spectrum-Thermal and Non-thermal Effects of Non-ionizing Radiation Exposure

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Abstract

Mark Twain said “there are three kinds of lies: lies, damned lies and statistics” and no less so when Australian physicist Victor Leach began taking a serious look at his country’s official statistics for non-ionizing radiation health matters. He found extreme bias in the selection of studies. Already in 1972, the U.S. Navy published a document listing over 2000 biological effects associated with exposure to non-ionizing radiation from Radio and Radar transmissions. Noted in the document is that most of the disorders were reversible. However, a comparison between those observations and those listed in a 2016 publication seems to confirm that the earlier study was at the very least a strong indicator. Nevertheless, for many years scientists have been deadlocked with the argument between thermal short term and biological long term non-thermal effects.

The original formula adopted for non-ionizing radiation protection was and still is to the Western World based entirely on the thermodynamics principle of transfer of energy and temperature rise within a very short time period. Although Eastern standards are not accepted in the West, alternative radiation protection limits have been developed by such organizations as the institute of Bau Biology, Germany which recommends limits based on average power density of the radiation. Other institutions include differentiation between the various modulation technologies.

Will radiation safety be improved with emerging technologies? Yes, no, maybe! The problem is that for any new communications technology such as 5G or LiFi it is impractical to conduct studies that could take years to produce any results. Although LiFi looks promising, because it operates in the visible light part of the spectrum, only time will tell. For example, LiFi automatically links with chronobiology, but circadian rhythm changes caused by exposure to non-ionizing radiation which are at the very heart of chronobiology are the very last effect listed on the previously mentioned 1971/72 U.S. Navy Report. There is a lot more going on in the “other half” of the spectrum than most people realize!

Keywords: Non-ionising radiation; 5G; safety.
Technology Upgrades at NMISA’s Radioactivity Standards Section

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Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAAPMB); Cape Town, South Africa; 28 October-1 November 2019

Introduction
Radio isotopes have been produced in South Africa since 1965, first with CSIR low-energy cyclotron and since 1988 with the National Accelerator Centre cyclotron. The task of performing accurate and precise measurements of radioactivity was undertaken by the National Physical Research Laboratory, today known as the National Metrology Institute of South Africa (NMISA). The Radioactivity Standards (RS) section of NMISA supports the nuclear medicine (NM) industry through primary measurements of radioactivity used to calibrate NMISA’s secondary standard well-type ionization chamber (IC) for various radionuclides, in order to provide services to radioisotope production and NM facilities. The primary measurement system utilizes analogue liquid scintillation counting (LSC), of which most components are over 35 years old. If these components fail, they are expensive to repair or replace, or support for the components are no longer available. To ensure continued support to the NM industry for measurements of new radiopharmaceuticals being developed, NMISA is replacing old balances and upgrading the primary measurement system from analogue to digital data acquisition (DDAQ).

Materials and Methods
A DDAQ system was procured, which occupies a spatial volume of only 0.027m³ compared to 2m³ of the analogue system. Instead of signal processing done via analogue electronics, the DDAQ system accepts signals directly from detector pre-amps. Signals are digitized and data stored in list mode format, providing greater flexibility for off-line data analyses, where parameters, settings and analysis windows can be optimized to produce more accurate and precise results. The DDAQ system thus eliminates the need for repeat measurements under varying parameters and settings, thereby reducing manual work and turn-around time for standardization of radionuclides used in NM. The DDAQ system also allows for remote measurements. A new micro-analytical balance (for accurate source mass measurements) and Co-57RV-rial (370MBq) dose calibrator reference standard source was also procured.

Results
The DDAQ system will be optimized and verified against the current analogue system by standardizing various radionuclides using both systems.

Conclusion
The DDAQ system provides a modern, convenient and time-saving method to standardize radionuclides, with accuracy and precision comparable to the analogue system.

Keywords: Digital data acquisition system; primary standard system; ionization chamber; micro-analytical balance.
Investigation of Potential Skin Toxicity for Patients Receiving Breast IORT using EBT3 Gafchromic® Film

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Introduction
At Netcare Milpark Hospital, intraoperative radiotherapy (IORT) is a treatment option for a select group of early stage breast cancer patients. The Carl Zeiss INTRABEAM® unit is utilized for these procedures. One limitation is the lack of image-guided pre-treatment plans, thus one is unable to anticipate the radiation dose delivered to the overlying skin. EBT3Gafchromic® film was utilized for this purpose.

Materials and Methods
EBT3 Gafchromic® film calibration was performed in the INTRABEAM® water phantom using the INTRABEAM®50k x-ray source. Absorbed dose to water could be determined using a PTW TN34013 soft x-ray ionization chamber along with a formalism specified by Zeiss. The irradiated film sections were scanned 42 hours later with an Epson V750Pro transmission scanner in 48-bit RGB mode and analysis was done using Image J. The calibration curve was verified at various dose levels before implementation. During each breast IORT case, after lumpectomy, one of the spherical treatment applicators (diameters ranging 3-5 cm) are placed into the cavity. The applicator is attached to the probe-like end of the x-ray source. A dose of 20Gy is prescribed at 0mm (at the surface of the applicator). During this study, a 1 x 1cm² section of film was placed onto the outer skin surface of the breast at a region where the skin-to-applicator distance is minimal. The film was kept sterile by enclosing it with 3M™ Tegaderm™ transparent wound dressing before placement onto the patient. The influence of the Tegaderm™ on the film measurement was also evaluated.

Results
For 83 patients that underwent the procedure, 14 received < 3Gy as a point dose on the skin surface and 25 received 3-5Gy. The majority of the patients (34) received skin doses in the 5-10 Gy range, and 10 received doses > 10Gy. The highest dose being 17 (±0.3)Gy for two patients. The dose measured by the film could be verified within 3.3% and the Tegaderm™ had negligible influence on the measurements.

Conclusion
EBT3 has shown to be a useful tool for determining skin doses for breast IORT patients.

Keywords: Intra operative; Skin Dose; Gafchromic Film.

https://globalmedicalphysics.org/
A Novel Treatment Planning Model for Total Skin Electron Irradiation

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Introduction

Mycosis Fungoides is treated using total skin electron irradiation (TSEI). Currently, no clinical treatment planning (TP) systems exist for electron TP at large source-to-skin distances (SSD). Using the EGSnrc/DOSXYZnrc MonteCarlo (MC) code, we have developed an electron beam characterization model for an Elekta® linear accelerator to perform TP and dosimetrically verified the model on an anthropomorphic phantom.

Materials and Methods

A dual point-source beam characterization model was constructed for 4-, 6- and 8-MeV electron beams, collimated to a 40x40 cm² field at iso centre. Existing phase space files were used to extract electron and photon beam characteristics. Water measured off-axis ratios (OARs) for each energy at multiple SSDs were dosimetrically matched by independent mathematical fluence profiles. Output factors (OFs), central axis (CAX) and off-axis (OAX) percentage depth dose (PDD) curves were also verified for SSDs between 100 and 200cm. An in-house full-body anthropomorphic phantom was made and CT scanned, requiring two half-body scans to be joined together in a single whole-body CT set. With this phantom positioned at 180cm SSD, 4 planes located from head-to-toe was simulated with various arc increments per plane to cover the entire phantom. ProSoma Core™ was used for dose evaluation after converting MC3D-dose data to DICOM format, and compared to in-vivo measurements.

Results

The beam characterization models produced CAX and OAX PDD curves, OARs and OFs to within 2% of measured data at 180cm SSD in water. As a clinical test case, simulations on a half-body phantom could be verified with in-vivo doses to within 3%. Subsequent whole-body simulations showed distinct hot-and-cold spots along larger diameter regions, emphasizing the need for dose optimization. Improvement of uniformity in larger diameter regions was observed when the number of beam angles were increased, however this is not required for smaller diameter regions.

Conclusion

The MC model compared very well to measured data in both water and in-vivo measurements. Dose uniformity can be improved by using more beam angles, but using an optimization approach for TSEI is encouraged to enable patient specific TP.

Keywords: TSEI; Monte Carlo; treatment planning.
The QUATRO Audit Experience at Tygerberg Hospital

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Introduction

Tygerberg Hospital applied to the International Atomic Energy Agency (IAEA) for a comprehensive audit of radiotherapy practices, the so-called QUATRO audit (Quality Assurance Team for Radiation Oncology).

Materials and Methods

The QUATRO audit is a tool for quality improvement. The IAEA sends a team consisting of a Radiation Oncologist, Medical Physicist and Radiotherapy Technologist (RTT) to assess the whole radiotherapy chain, including aspects such as organization, infrastructure and clinical and medical physics components. The objective of such an audit is to review and evaluate the quality of all the components of the radiotherapy practice at an institution, including its professional competence, with a view to quality improvement. A major part of the audit is patient oriented.

Results

An internal audit team was setup in the hospital to work through the check lists initially, which in itself is an invaluable exercise, usually pointing out weaknesses quite clearly. The actual audit was done in November 2018. A large part of the audit consists of ticking off relevant checklists. The audit team spent a week in the department observing procedures, studying documentation, policies and procedures, interviewing staff members, following the work flow in the department and doing independent dosimetry checks.

Conclusion

Unfortunately the final audit results have still not been submitted to the hospital by the IAEA. The audit team stated in their exit briefing that they observed a “culture of quality in radiotherapy”, which is high praise for the hard work that has gone into improving services. Independent absolute dosimetry was within ± 1% for all beams except one, where a 1.7% difference was observed. The team specifically commended the “time-out” check sheets at each machine. A QUATRO audit is recommended as best practice.

Keywords: QUATRO; audit; safety culture.
Towards Breast Cancer Detection without Images; the Hidden Power of Microwave Sensing

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Introduction

Breast cancer mortality is higher in remote regions in Canada and in developing countries where access to early detection is limited. Mammography, the standard for breast cancer screening, uses ionizing radiation, requires breast compression, has a high false-positive rate and requires a well-established human and capital infrastructure. Breast Microwave Imaging (BMI) for cancer detection uses non-ionizing radiation, is low cost, portable and potentially has improved sensitivity and specificity when compared to traditional mammographic x-ray techniques. Radar-based techniques illuminate the breast with wide band microwave signals and record the scattered electromagnetic field. Previous approaches have made several assumptions that limit reconstruction performance. These assumptions include a single estimated propagation speed which may not be reflective of the true propagation speed in the breast and a simple signal model of the beam characteristics, which assumes an isotropic beam pattern. This presentation is a tour through time and place: starting with simple experiments that showed the benefits of microwave imaging and finishing with advanced artificial intelligence approaches that are capable of detecting lesions even when they may not be visible.

Materials and Methods

This work presents the development and validation of microwave tools and techniques, including the use of the inverse chirp transform (ICZT) for converting our frequency domain VNA to high-quality time-domain measurements and the development of iterative Delay and Sum (it-DAS) based reconstruction algorithms that allow for adjustable propagation speeds and beam characteristics. The itDAS algorithm adopts the functional form of the MLEM algorithm with a radar model used as the forward projection operator, and the back projection operator being the DAS algorithm. Data was gathered using our rotating radar-based BMI system, which has been licensed as a Class II Medical Device by Health Canada, using a stepped-frequency continuous-wave form microwave signal over 1-8 GHz, as well as by simulations of a portable system prototype. The monostatics can configuration used the $\frac{S11}{2}$ scattering parameter measured with a VNA at 72 positions along a circular trajectory. The algorithms were tested with an array of 3D printed anthropomorphic phantoms of various breast sizes, densities, and with different tumor configurations. Algorithm performance was evaluated using the signal-to-mean ratio (SMR), the signal-to-clutter ratio (SCR) and Receiver Operator Curves (ROC). Several machine learning classifiers have been trained to predict the presence or absence of tumor tissue from the scattered electromagnetic field calculated using numerical breast models.

Results

The itDAS algorithm produced reconstructions from phantoms with significantly higher SMR than the DAS method and significantly higher SCR for the reconstruction in large, dense phantoms. The intensity of clutter in both images produced by the itDAS algorithm was significantly lower than in reconstructions produced by the DAS method. The iterative structure of the itDAS method allows for the incorporation of correction factors into the forward projection operator to further improve the signal model by modelling the beam pattern and frequency-dependent gain of the antennas, the inhomogeneous propagation speed of the microwave signal, and the signal attenuation in the breast. Image quality was found to vary slowly with propagation speed and did not change significantly within a 10% range. The performances of the machine learning algorithms will be presented and discussed, with some classifiers achieving cancer detection metrics similar or better to those obtained by current X-Ray mammography.

Conclusions

This work presents the development of tools and techniques for in-air breast microwave imaging and sensing. Images produced by the itDAS algorithm had greater signal-to-mean ratios and greater signal-to-clutter ratios than those obtained using the DAS method. The iterative structure of the itDAS method allows for the incorporation of correction factors into the forward projection operator to further improve the signal model by modelling the beam pattern and frequency-dependent gain of the antennas, the inhomogeneous propagation speed of the microwave signal, and the signal attenuation in the breast. Further improvements that can be achieved with the algorithms will also be described and the benefits of these approaches for improving the sensitivity and specificity of breast cancer detection, particularly in denser breasts, will be discussed.

Keywords: Microwave radar; Breast imaging; Machine learning; Delay-and-Sum.

https://globalmedicalphysics.org/
Evaluation of Radiation-Induced Changes in the Expression of Bcl2, Parp-1, PI3K, Hsp90 Pathway-Related Genes in Cancer Cell Lines

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Introduction
Radiation therapy is a form of cancer treatment that utilises the ability of ionising radiation to damage DNA molecules, making cells to go into apoptosis. However, activation of some signalling pathways can promote cell survival after radiation-induced DNA damage. The purpose of this study is to examine the differences in expression levels of genes related to the Bcl2, Parp-1, PI3K, and Hsp90 pathways that may influence either cell death or cell survival.

Materials and Methods
Four human cell lines (three breast: MDA-MB-231 (cancer), MCF-7 (cancer), MCF-12A (normal); one lung: A549 (cancer)) were irradiated with X-rays to doses of 0-10Gy for cell survival, and 6Gy for gene expression measurement. Intrinsic radiosensitivity was assessed, using the colony forming assay. The expression levels of genes after X-ray exposure were measured with a custom human pathway RT2 Profiler PCR Array, using real-time polymerase chain reaction.

Results
The surviving fractions at 2 Gy for the MDA-MB-231, MCF-7, MCF-12A and A549 cell lines were 0.39, 0.19, 0.51 and 0.49, respectively. The MCF-7 cell line was thomsensitive to radiation, whereas the MCF-12A cell line showed the highest radioresistance. Gene expression data analysis revealed that several genes were differentially expressed between treated and untreated cell cultures. The following genes, with fold regulations: Bcl2a1 (21.91), Tp53 (87443.75), Rad51 (11.66), and Fox1 (65.86), were highly over-expressed, and Bax (-127.21), Fox1 (-81.79), Pdpk1 (-1241.78) and Brca1 (-8.70) were highly under-expressed in the MDA-MB-231, MCF-7, MCF-12A and A549 cell lines, respectively.

Conclusion
These results indicate that differentially expressed genes after X-ray irradiation may be used as potential targets for modulating radio-responsiveness.

Keywords: Apoptosis; Radiosensitivity; Gene expression; PCR array.
Assessment of Nuclear Medicine Radiation Protection Practices among Radiographers and Nurses at a Small Nuclear Medicine Department in a Tertiary Hospital, South Africa

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Introduction

Radio pharmaceuticals are used for diagnosis, treatment, staging and follow up of various diseases. However, there is concern that the ionizing radiation (gamma rays, α and β particles) emitted by radio pharmaceuticals may result in exposure of radiographers and nurses who may have limited knowledge of the principles of radiation protection and safety, raising the risk of cancer. This study aimed at investigation radiation safety awareness levels among radiographers and nurses at a small tertiary hospital in South Africa.

Materials and Methods

An analytical cross-sectional study was done. A validated two-part questionnaire was implemented to consenting radiographers and nurses working in a Nuclear Medicine Department. Part 1 gathered demographic information (age, gender, work experience, attendance to/or passing ionizing radiation protection courses). Part 2 covered questions related to knowledge and awareness of radiation protection principles.

Results

Six radiographers and five nurses participated (27% males and 73% females). The mean age was 45 years (age range 20-60 years). The study revealed that neither professional development courses nor radiation protection courses are offered at the Nuclear Medicine Department under study. However, 6/6 (100%) radiographers exhibited a high level of awareness of radiation safety principles on handling and working with radio pharmaceuticals which correlated to their several years of experience. As for nurses, 4/5 (80%) showed limited knowledge and awareness of radiation protection principles irrespective of the number of years in the profession.

Conclusion

Despite their major role of caring for patients undergoing diagnostic and therapeutic treatments, the nurses showed limited knowledge of ionizing radiation side effects. Furthermore, unlike their international counterparts, the nurses never received any formal basic radiation safety training. Radiographers benefit from radiation safety refresher courses, while a basic radiation safety course is recommended for nurses, because of their important role in caring patients who may be radioactive post therapeutic or diagnostic procedures. Awareness of radiation safety among nurses is crucial in order for them to respond appropriately in scenarios where a radiation accident occurs during the caring of patients.

Keywords: Radiation safety; radio pharmaceuticals; ionizing radiation.

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Commissioning and Operating a New Personal Radiation Monitoring Device (PRMD) Service in South Africa: A One Year Review of Data

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Introduction

In South Africa (SA), it is required that, all radiation workers must be monitored using a PRMD supplied by an approved provider. PRMD technologies have evolved over time from earlier film and thermoluminescent based dosimeters to the current standard being Optically Stimulated Luminescence (OSL) dosimeter technology. The OSL dosimeter technology uses an aluminum oxide crystal structure doped with carbon (Al2O3: C) that offers many advantages like: high sensitivity, non-destructive readouts and improved environmental stability. Unfortunately, SA doesn’t have an approved PRMD provider that uses OSL technology. The aim of this project is to commission and operate a new PRMD service in South Africa utilising OSL dosimeter technology and to evaluate the data generated.

Materials and Methods

Commissioning a new PRMD service in SA requires: South African Healthcare Products Regulatory Authority (SAPHRA) approval; South African National Accreditation Services (SANAS) ISO/IEC17025: 2017 accreditation and; registration with the National Nuclear Regulator (NNR) National Dose Registry (NDR). The new PRMD service, named Dosimeter Services (Pty) Ltd, has been commissioned using OSL dosimetry technology, readers and Individual Monitoring Lab Software (IMLS) supplied by Landauer®.

Results

The new PRMD service was successfully licensed and obtained all the required accreditation to operate commercially using OSL technology in SA. The service currently monitors 2102 radiation workers primarily in the private health care sector. The personal dosimetry records for the first year of operation indicate that the distribution of radiation workers are 54.7%, 17.5%, 17.2%, 7.2% and 3.4% in respectively general theatres, interventional theatres, emergency departments, general radiology and radiotherapy. The highest personal doses were measured in the interventional theatre environments.

Conclusion

The improved sensitivity and accuracy that OSL offers was found to be valuable for Radiation Protection Officers (RPO) and the medical physicists when evaluating if radiation worker doses are within safe levels and when to investigate any irregularities.

Keywords: Optically Stimulated Luminance (OSL); Personal Radiation Monitoring Device (PRMD); Radiation worker; Dosimeter; Personal Dosimetry.
Abstracts of the 57th National Congress of the South African Association of Physicists in Medicine and Biology (SAAPMB); Cape Town, South Africa; 28 October-1 November 2019

The Status of Medical Physics in South Africa

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Introduction

The South African Association of Medical Physicists was established in February 1960 by 9 medical physicists, this was later to become the South African Association of Physicist in Medicine and Biology (SAAPMB). As of October 2018, the HPCSA has 156 medical physicist and 27 interns registered in South Africa (obtained from the HPCSA website). Currently, the SAAPMB membership consists of 119 full members and 71 associate/student/retired/honorary/institutional members. This presentation will discuss the distribution of medical physics and medical physicists within South Africa and the effects this has on medical physics community.

Discussion

There are currently 134 medical physicists and 28 intern medical physicists working in South Africa according to a questionnaire sent out to both public and private institutions earlier this year. There are 61 medical physicists working for public institutions with 59 being full time and 2 being 5/8th positions. The remaining 73 are distributed mainly in private health care with others working for the National Metrology Institute (NMISA), the National Regulators (Radiation Control, SAHPRA) or industry. The majority of medical physicists in South Africa are based in Radiotherapy (63.5%) followed by Radiology (12.5%), Nuclear Medicine (9.5%), industry (6%), university appointed (4.5%) and NMISA and SAHPRA (both at 2%).

Conclusion

There are 13 known public medical physics departments in the country and out of these seven institutions offer clinical training in medical physics. Four of the seven institutions also offer academic training in medical physics with one starting at undergraduate level and the rest from Honours. Out of these seven training institutions, all except 1 currently have at least 2 medical physics interns. PhD and Masters Degrees are offered by five of the seven institutions. Further discussion and breakdown of distribution and education of Medical physics in South Africa will be presented in the presentation.

Keywords: Education; Medical Physics; Distribution.
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The ICMP Congress–Let’s Imagine the Future Together

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Introduction
The 24th International Congress on Medical Physics (ICMP) was hosted in Santiago, Chile, from 8–11 September 2019. The congress was hosted jointly with the 8th Latin American Association (ALFIM) congress and 2nd Chilean Medical Physics Society (SOFIMECH) congress.

Materials and Methods
The congress was attended by 493 registrants from 54 countries. The congress had up to eight parallel sessions and included various invited speakers, plenary sessions, workshops, symposia and courses. There were 109 oral presentations and 260 e-posters on various topics: Diagnostic and Interventional Radiology, Radiation Oncology, Nuclear Medicine, Radiation Protection, Education and Professional Issues, Reference-Quality Dosimetry and Non-Ionizing Radiation. Additionally, the ICMP congress serves as an opportunity for the various organizational bodies to meet.

Results
I attended as SAMPS delegate to the IOMP, but also represented FAMPO in the regional co-ordination board meeting. I had one poster on the “Claws”, a unique gold applicator that uses I-125 seeds in the treatment of retinoblastoma. Additionally, I was asked to chair one session and presented on the role of FAMPO in medical physics capacity building in the region.

Conclusion
The congress was hosted successfully. Fantastic speakers were arranged for the congress. Some sessions were held in Spanish, with a mix of local and international speakers, about topics of interest to Latin American physicists.

Keywords: ICMP congress; FAMPO; SAMPS.

See http://www.za-mp.org/
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Using C-arm Imaging to Determine ICRU Points in 2-DHDR Brachytherapy for Cervical Cancer

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Introduction
HDR brachytherapy plays an important part in the treatment of cervical cancer. Our institution makes use of a 2-D treatment procedure using an S-Tube to increase patient throughput. Bladder and rectum points as per ICRU are needed as part of the treatment and reporting processes. A C-arm unit is available in the Brachy room to verify applicator placement and aid in the determination of the ICRU points. The C-arm is non-isocentric and does not have the mechanical accuracy of a simulator or CT scanner. Orthogonal reconstruction of the C-arm radiographs produces unwanted magnifications. This makes it difficult to place the bladder and rectum points according to ICRU 32. A different method of reconstruction was investigated to overcome this problem.

Materials and Methods
Three C-arm radiographs were obtained at 0-, 45- and 90 degree angles after the S-Tube with applicator and X-ray markers were placed in the cervix. The orthogonal reconstruction method was applied to the 0 and 90 degree images and the ICRU bladder and rectum points were placed. Dose to these points were recorded. Afterwards, the variable angle method was applied to all three radiographs and bladder and rectum ICRU dose points were placed and recorded.

Results
For 6 patients, the orthogonal method versus variable angle method produced a significant lower dose to the bladder and rectum points. This point to a possible under estimation of the bladder and rectum point doses. The magnification problem from AP to LAT image is resolved if the 3rd image is added and this allows the ICRU points to be placed correctly.

Conclusion
Variable angle reconstruction method produces higher dose values to the bladder and rectum ICRU points which is more trustworthy, since the point scan be placed per ICRU instructions. The addition of a 3rd image does not have a significant impact on the imaging time per patient or patient throughput.

Keywords: Brachytherapy; Cervical cancer; Treatment Planning.
Quantifying the Attenuation of Carbon Fibre Treatment Couches in the Monaco® Treatment Planning System (TPS)

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Introduction
Carbon fibre treatment couches on modern linear accelerators provide a strong, rigid framework for patient support. Patient safety is a priority, therefore the dosimetric properties of treatment couches need to be investigated and accurately incorporated in treatment plans, as it can significantly reduce differences between planned and delivered dose. The aim of this study is to determine the dosimetric impact of treatment couches on posterior (and posterior oblique) fields and to validate the implementation thereof in the MONACO® TPS in the Radiation Oncology Department at Tygerberg Hospital.

Materials and Methods
Attenuation measurements were performed on the ELEKTA Connexion Imaging and Central Opening Module couches of the ELEKTA Precise and Synergy (with Agility head) linear accelerators. Measurements were made in RMI H57 solid water (30 x 30 x 30 cm³) slabs using a PTW Farmer-type ionization chamber (TW30013) positioned at the accelerator’s isocentre. Measurements were taken at 10° intervals for photon energies in clinical use. The percentage attenuation was calculated as the ratio of the electrometer readings for parallel-opposed fields. The Computed Tomography (CT) dataset of the couch tops and solid water phantom were obtained on a Philips Brilliance BigBore 16-slice CT scanner and exported to the ELEKTA MONACO v15.11.02TPS. The individual couch structures were delineated and density values were assigned using the commissioned CT-to-ED curve. Couch structures were saved in the positioning device library and imported in to the phantom test plans. These treatment plans were generated with 100MU per field at 10° gantry intervals for all photon energies.

Results
The percentage attenuation was calculated and determined to be within 3% for beams perpendicular to the couch surface. The maximum attenuation was observed for oblique fields which was significantly higher than the manufacturer specified values. On validation on the TPS, MONACO® accurately quantified the attenuation to within 1% of the measured values, except for the wide oblique angles of the Central Opening Module couch where it was overestimated by up to 4% compared to measured values.

Conclusion
Couch attenuation differs significantly with gantry angle and beam energy. As a result, a single-value correction approach would not be suitable and the treatment couch should be included in all treatment planning calculations.

Keywords: Treatment Planning; Treatment Couches; Attenuation.
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Investigation of Staff Radiation over Exposures at Tygerberg Hospital between 2012 and 2019

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Introduction
The objective of the study was to review personal radiation monitoring dosimeter (PRMD) overexposures at Tygerberg Hospital (TBH) over an eight year period. Any PRMD that received a radiation dose of more than 4mSv in a single wearing period was investigated as per Radiation Control/SAHPRA directive.

Materials and Methods
PRMD reports for TBH were reviewed after readout by the Radiation Protection Service at SABS. If an overexposure was reported the staff member was contacted and a detailed report of the possible overexposure established. It was noted where the staff member had been working and if they could recall an incident. All overexposure reports were sent to Radiation Control/SAHPRA who would then decide to allocate or reverse the dose the staff member had received.

Results
Radiation overexposures ranged from 4mSv to 48mSv. Of the 13 instances of reported overexposures, 6 were due to an incorrectly worn PRMD, 7 were due to the PRMD being left in a screening or treatment room unintentionally.

Conclusion
We can conclude that the TBH radiation monitoring service is working effectively. Trends are identified, and corrective measures can be put in place. If an overexposure occurs, most staff reports it immediately. We are then aware that a staff member’s radiation dose could exceed the 4mSv wearing period limit.

Keywords: PRMD; TBH; radiation overexposure.