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Evaluation of the stability of healthy volunteers aligned for whole brain irradiation without a mask

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Essential for irradiations of brain tumours is an exact alignment of the patient. Today, it’s commonly realised with different mask-systems. However, some patients show acute symptoms like seroma or inflammations, which lead to changes of the patient’s surface. These changes may require a change in the shape of the mask, too. Some optical monitoring systems for patients, like the Optical Surface Monitoring System (OSMS) by Varian (Palo Alto, USA), are able to monitor the patient during the entire treatment. An analysis with healthy volunteers has been performed to evaluate the stability of an alignment for brain tumour irradiation without a mask, only by monitoring the patient with OSMS. The volunteers were fixed with tape, which was placed on the forehead and stuck on both ends of the couch, on a head-supporting-device. After the alignment a reference surface was recorded by OSMS. With this reference, the rotational and translational movements of the volunteer during a maximum time of 15 minutes were recorded every 10 seconds. As a second part of this study, after the monitoring the volunteers were realigned three times to evaluate the consumed time for the system. Within the first 5 minutes the average movements were in translational directions below 3 mm and rotational below 2°. The mean alignment time was below 1 minute. The measurements confirm that within the time, which is necessary for a whole brain irradiation, the volunteers remain firm with this system. Additional the OSMS is capable to perform a beam hold, if the patient moves beyond the given thresholds. For further estimations it’s essential to perform more studies with real patients, since they’re in a psychologically challenging situation. Furthermore, the alignment didn’t take an additional expenditure of time.

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Effective workflow for radiation therapy departments with many VMAT irradiations through the use of Mobius 3D and Fx for plan-related quality assurance and a simple and pragmatic machine-related quality assurance program

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In radiotherapy departments with many VMAT irradiations quality assurance is a timeconsuming factor. Both planning-related quality assurance and machine-related quality assurance often take more time than planning itself. The Mobius 3D and Mobius Fx programs were introduced with the intention of minimizing the time required for the planning-related quality assurance. Mobius 3D and Mobius Fx both make an independent computational check of the monitor units, but also of the 3D dose distribution (gamma analysis) and the DVHs. The calculation with Mobius Fx is based on a logfile which records all relevant machine parameters during irradiation. The use of Mobius 3D and Fx fulfil the requirements of the DIN 6875-3 and 6875-4. In addition, a machine-related quality assurance program suitable for VMAT must be established. For this purpose, suitable VMAT standard plans have been introduced, which are radiated in the sense of a constancy check at the Linac and measured with Delta4 from Scandidos. To proof the sensitivity of these standard plans, machine errors were introduced and machine parameters disadjusted: beam-energy, flatness of cross-sectional profiles, calibration of jaw and mlc positions. The values for maximum leaf speed, maximum dose rate and maximum gantry speed were llimited. Summary of results: The time saving through the use of Mobius 3D and Fx with regard to plan-related quality assurance is enormous. The calculation results of Mobius agree more than 99% with the calculations of the planning system, e.g. always better than 95% when comparing dose distribution with gamma criterion 3% / 3mm. The measurement of the standard plans lead to the conclusion that many machine parameters, which should be regularly checked according to DIN 6875-4, can be recorded very effectively with a single measurement. In the case of relevant deviations, this is immediately reflected in the measurement results of the standard plans.

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QALender – a web-based system for supporting quality assurance in radiation therapy

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In radiotherapy, devices have to be tested and checked regularly in order to ensure patient safety and to fulfill current regulations such as DIN 6847-5 and DIN 6875-4. In most institutions, radiation physicists are working with paper-based checklists or Excel sheets. This does not support sustainable and efficient documentation management, long time evaluation, reminders for periodic tests and checks, online validation of readings or aggregated measurements.
We developed a web based Document Management System (DMS) to support Quality Assurance (QA) in radiation therapy. It allows to design clearly arranged measurement protocols according to the needs of specific departments, devices and regulations, and to fill them in online with measurements taken. It facilitates a review process and persists the resulting protocols as pdf documents. The system features a calendar and automated reminders.
We used Python 2.7 and the Django 1.9 Web Development framework running on an Apache2 Web server on an Ubuntu 14.04.0 LTS virtualized machine for our implementation. The database model allows for flexible document template generation including user-defined calculation of derived values and flexible layout for all parameters.
The QA protocols used in the University Hospital Tübingen were used as first draft for the web based protocols. The process of measuring parameters and the overall quality assurance tasks were defined by radiation physicists and refined by interviews.
The system allows flexible document generation and has been used in parallel to the routine documentation in the University Hospital Tübingen. Up until now over ten templates were used and measurements were taken. QAlender was well received by the radiation physicists, and due to their feedback, the handling and front end was optimized. More features are going to be implemented. We will do a formal evaluation of the benefits of the system in the next project phase.

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Influence of TomoTherapy-specific planning parameters on technical treatment parameters and dose distribution

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TomoTherapy offers a helical delivery of intensity modulated photon beam. The binary MLC generates many small fields within each projection, which necessitates dosimetry in small photon fields, one of the main challenges in clinical dosimetry.
The influence of TomoTherapy-specific planning parameters such as pitch, modulation factor and the number of iterations on average subfield size and further treatment parameters as well as clinical dose distributions were investigated. The planning parameters were combined, thus this study contains 30 plans for two different clinical cases.
A subfield in helical TomoTherapy was defined as the area projected into the isocentric plane which is collimated by directly adjacent leaves in x – and by the jaws in y – direction within one projection. With an in-house matlab tool, the fluence and opening-time weighted average subfield sizes were extracted from the dicom plan.
The further treatment parameters investigated were the actually used modulation factor, the average leaf opening time, the percentage of leaf opening times smaller than 70ms, and the gantry period.
Homogenity index, coverage index, conformity index and some dose constraints for regions at risks were compared to determine the influence on the dose distribution.
The more iterations and the higher the nominal modulation factor, the smaller are the average subfield sizes. The average square field lengths are between 3.5cm and 1.8cm for the investigated range of planning parameters.
A high complexity of the plan, e.g. high nominal modulation factor, low pitch and/or large number of iterations, improves the clinical dose distribution.
The higher the number of iterations, the lower is the used modulation factor, especially for high nominal modulation factors. The average leaf opening time increases with the number of iterations and the nominal modulation factor. However, the percentage of leaves with a leaf opening time smaller than 70ms increases with the nominal modulation factor.

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Dosimetric characterization of microbeams for radiation therapy at the Munich Compact Light Source

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Microbeam radiation therapy (MRT) is a preclinical technique in radiation therapy which employs irradiation of the tumor with a spatially fractionated beam. In our experiment, a tungsten grid in the beam produces 50 µm wide high-dose channels (peaks) alternating with 300 µm wide low-dose areas (valleys). Potential advantages of MRT are a higher tolerance of healthy tissue and thus increased tumor control in comparison with homogeneous irradiation. This therapy method is currently investigated in an in-vivo-experiment with tumor-bearing mice at the Munich Compact Light source, a compact laser-undulator synchrotron source for quasi-monochromatic X-rays tuned to 25 keV. For these experiments, an exact dosimetry and characterization of the beam is necessary, which requires a high spatial resolution and a wide dynamic dose range of the dosimeter. This was achieved by irradiation of radiochromic films (Gafchromic EBT3) with different exposure times to account for the different dose rates in peak and valley, so that on one film the dose in the peaks and on another the dose in the valleys was in the detectable range. The films were evaluated using a microscope, and combination of the films yielded the overall dose distribution. A critical parameter of MRT and its efficiency is the peak-to-valley-dose-ratio (PVDR), which was calculated from the films to be 210 ± 10. For comparison, the complete irradiation setup was also modelled using the Monte Carlo simulation toolkit Geant4. The dose distribution in the film was simulated, varying different parameters like distances of the peaks or beam shape, and evaluating their influence on the dose distribution and the PVDR. The simulation and the measurements are in reasonable agreement, with the simulation yielding 25% lower valley doses than the measurements, resulting in a PVDR of 280 ± 20.

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Evaluation of new gantry angle dependence correction factors for pre-treatment IMRT plan verification with MatriXX Multicube Lite® and myQA®

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The MatriXX® detector has a known chamber response dependence of the gantry angle which can lead to considerable deviations in the gamma passing rates if the detector is not oriented perpendicular to the beam. Together with the Mul-ticube Lite® phantom the detector is positioned on the treatment couch and gantry angle dependent correction factors are needed to maintain the accuracy of measurements. This study investigates the influence of different gantry angle look-up tables (LUTs) for 6 MV photons and the overall performance with myQA®.

myQA® is a quality assurance software (IBA Dosimetry, Schwarzenbruck, Germany) which combines machine quality assurance and patient plan verification. To evaluate the IMRT quality assurance with myQA patients® treatment plans of 15 patients (VMAT, dMLC and SaS) were calculated into the geometry of the MatriXX Evolution™ (IBA) in com-bination with a water equivalent phantom (Multicube Lite™, IBA). The measurements were performed on a 6 MV El-ekta Synergy® machine (Elekta, Stockholm, Schweden) using a fixed setup on the couch and a gantry angle sensor at-tached to the gantry. Afterwards, correction factors were calculated as the ratio of measurements and dose prediction obtained with the TPS (MONACO® v.5.1, Elekta). Original and improved LUTs were applied to the measurements. For evaluation gamma index analyses with 3%/3mm and dose profile comparisons were performed.

With the application of both LUTs the gamma index improved by a mean of 11.2 %. Overall, the correction led to the passing of on average 67 % more of all plans compared to the uncorrected measurements. The gamma passing rate between both LUTs showed an average difference of 0.05 %. Hence, the improved algorithm of the new LUT confirmed the reliability of the original LUT and the myQA® software is a promising method to verify patient plans especially for VMAT cases.

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PRONTOX – a prospective randomized clinical trial for the treatment of non-small cell lung cancer patients at the University Proton Therapy Dresden

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Patients with advanced non-small cell lung cancer have a low overall survival despite intense radiochemotherapy. Radiotherapy is often limited by the toxicity in the surrounding healthy tissue of the lung, oesophagus, spinal cord and heart. The prospective randomized clincial trial PRONTOX (NCT02731001) aims on the analyses of toxicities in patients treated for advanced lung cancer with either photon therapy or proton therapy. Only patients with tumor motion <10 mm are included. Photon and proton treatment plans are created based on time-resolved computed tomography (4D CT) imaging. Both plans are independently evaluated by experienced physicians for their applicability. If both treatments are deemed acceptable in terms of dosimetric parameters, randomization is executed. The dosimetric analysis includes the evaluation of the individual tumour motion and the uncertainties in range (3.5%) and set-up (±3 mm) for the proton treatment. During the treatment, respiratory surrogate signals were recorded for evaluation of breathing variabilities. In addition, control 4D CT were acquired once a week during treatment.
End of March 2017, three patients (all stadium IIIB) were included, of which two had already finished their treatment getting double-scattered proton therapy. For the three patients, tumour motion was negligible and had only small effects on the dose distribution. The additional uncertainty analyses revealed the robustness of the generated proton therapy plans against the individual motion (maximum motion amplitude <2 mm) as well as range and set-up uncertainties. Based on the control 4D CT, changes in the patient anatomy and tumour motion were assessed. For the two patients who already completed treatment, the effect of anatomical changes and tumour motion changes on the fractional and accumulated dose distribution was small. No intervention e.g. a treatment plan adaptation was required in any case. Follow-up showed no recurrence and no side effects for these two patients so far.

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Density calibration of X-Ray CT using flash proton radiography for ion beam radiotherapy

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Precise localization of the target volume and surrounding organs at risk (OAR) as well as the accurate determination of the density distribution is the basis of an effective cancer treatment with ion beams. The standard procedure, using X-ray CTs, implicitly requires the conversion of photon absorption coefficients into ion stopping power. In practice this is performed by a semi-empirical look-up table. This may result in deviations of up to three percent, affecting the ion range calculation and thus impeding treatments close to OAR. In this presentation, we propose a new procedure for calibrating clinical X-Ray CT data using a density distribution obtained by flash proton radiography, therefore avoiding the uncertainties of CT-value conversion and allowing a more precise cancer treatment. Flash proton radiography has been in use for decades in high energy density physics and material science. Recently, the Biophysics Department at GSI Darmstadt, in collaboration with the Los Alamos National Laboratory, has shown its potential for medical applications as well, achieving a spatial resolution in soft tissue in the micrometer range. Encouraged by these results, we focus on the density resolution in proton radiographs of tissue equivalent materials (such as PMMA), with uncertainties below one percent. The acquired density distribution is then used to recalibrate CT data obtained from clinical scanners. The benefits and limits of the procedure introduced will be evaluated using the GSI treatment planning software TRiP98.

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Dose calculation based on Hounsfield Unit calibrated cone beam CT images

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In clinical routine Cone Beam Computed Tomography (CBCT) is used for daily patient positioning but cannot be used directly for daily dose calculations because of the limited image quality. The purpose of this work is to evaluate dose calculation on CBCTs calibrated with the Elekta Hounsfield Unit (HU) calibration algorithm ($CBCT_{HU}$) compared to a conventional planning CT (pCT) and to a scatter correction approach ($CBCT_{cor}$). The scatter correction uses the pCT as a prior to correct the CBCT projections for scatter, facilitating dose calculation on the $CBCT_{cor}$.
We used the Catphan Phantom (Phantom Library), the Gammex Phantom (Sun Nuclear), a PMMA cylinder with Gammex inserts and a 3D printed head phantom (RTsafe, originally used for gel dosimetry). Dose was calculated with the Collapsed Cone algorithm in the treatment planning system Oncentra (Elekta).
CT numbers in HU of the $CBCT_{HU}$ and of the $CBCT_{cor}$ were compared to the corresponding pCT values. For low density structures in the phantoms the mean HU value of $CBCT_{HU}$ and of $CBCT_{cor}$ were within 40HU of the pCT values. In the bony structure the mean HU value of the $CBCT_{HU}$ was 100HU above the pCT value whereas for $CBCT_{cor}$ the mean value was 20HU below the corresponding pCT value. The head phantom with a generic Glioblastoma treatment plan was used to evaluate dose distributions. The mean relative dose difference compared to the pCT for a representative PTV was less than 1% and 0.1% for $CBCT_{HU}$ and for $CBCT_{cor}$, respectively. The maximum relative difference was 3.4% and 2.3% for $CBCT_{HU}$ and for $CBCT_{cor}$ respectively.
A sufficient dose accuracy on $CBCT_{HU}$ was found in the preliminary phantom study. In a next step the study will be extended to real patient data, beginning with brain and head and neck cases.

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Lessons learned about small field dosimetry from the commissioning of a secondary Monte Carlo dose calculation engine for cyberknife

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Recently, ScientificRT GmbH have developed a Cyberknife plan interface for their fast Monte Carlo dose calculation tool SciMoCa. Here, we present results from the commissioning of this Monte Carlo engine for a Cyberknife M6 with different detectors for small field beam data acquisiton. A SRS diode type PTW 60018 (unshielded) and a microDiamond detector type PTW 60019 were used for the beam data measurements in a water tank for the Monte Carlo commissioning.
Since the actual field sizes for the Cyberknife fixed cones can differ from the nominal sizes by more than 1mm, precise measurements are necessary for the commissioning. While unshielded diodes are often used for Cyberknife beam data measurements, comparisons with the microDiamond detector showed remarkable differences in the out-of-field low dose regions as well as for the output factors. The Monte Carlo calculations confirmed that the SRS diode shows a distinct overresponse in the low dose regions, which gets higher with increasing measurement depth and seems to be specific for the spectral characteristics of the Cyberknife beam.
Using the microDiamond data, validation of the Monte Carlo beam model yielded good agreement with the measurements. Maximum deviations in the penumbral regions of the cross profiles amounted to 1/10 mm. The output factors agreed within ±0,3%.
The results show that the Monte Carlo dose calculation can be used to detect inconsistencies within a set of beam data measurements, and illuminate new aspects regarding detector selection for Cyberknife beam data measurements. Because of the high accuracy, the Monte Carlo dose engine in future could also be used as reference for the evaluation of additional dose calculation algorithms that are in clinical use for Cyberknife, such as the newly introduced Pencil Beam algorithm for the InCise2 MLC, and for the recalculation of patient treatment plans.