Documentaţie pentru fizicieni medicali

Tehnici dozimetrice aplicate în radioterapie

Descriere

Dozimetria reprezintă ştiinţa pe baza căreia se determină dozele de radiaţii determinate prin măsurători, calcule sau o combinaţie a acestora. Un termen folosit frecvent în acest domeniu este doza absorbită care reprezintă cantitatea de energie a radiaţiilor depozitată într-un ţesut, împărţită la masa ţesutului.

Doza absorbită este cel mai important factor fizic care influenţează răspunsul tumorilor şi al ţesuturilor normale la radiaţie. Cu cât este mai mare doza absorbită de un ţesut normal cu atât sunt mai probabile efectele toxice nedorite ale radiaţiilor.

Dozimetria radiaţiilor este extrem de importantă în tratamentul cu radiaţii externe şi interne. Măsurarea dozelor de radiaţii este efectuată frecvent de către fizicienii medicali atât la folosirea tehnicilor de radioterapie standard cu fascicul extern sau prin nrahiterapie, dar şi în cazul folosirii radiofarmaceuticelor pentru diagnostic sau tratament.

Pentru efectuarea dozimetriei radiaţiilor, fizicienii medicali colaborează cu medicii pentru stabilirea dozei exacte de radiaţii necesare distrugerii tumorilor, protejând, în acelaşi timp, cât mai bine organele la risc adiacente tumorilor, asigurând în acest fel un tratament eficient şi sigur pentru fiecare pacient.

Documentul este organizat în felul următor:

1. datele de identificare a articolelor (autori, titlu, anul apariţiei, volum, pagina de început şi sfârşit/numărul articolului, adresa DOI.
2. abstractul articolului
3. concluziile articolului

Imaginile şi textele prezentate pot fi subiectul unor acorduri de copyrights şi sunt prezentate doar în scop ilustrativ şi didactic.

Lista articolelor propuse

Articol 1

Mahesha Jayakody, Jeyasingam Jeyasugiththan, Chrishanthi Rajasooriyar, Arun Chougule, Dosimetry procedure to verify dose in High Dose Rate (HDR) brachytherapy treatment of cancer patients: A systematic review, Physica Medica 96 (2022) 70–80, https://doi.org/10.1016/j.ejmp.2022.02.022

Abstract

High dose rate (HDR) brachytherapy is a widely accepted cancer treatment method which provides high cure rates. In a HDR brachytherapy treatment, high radiation doses are delivered to the tumor area by placing the radioactive sources in the close proximity to the region of interest. The rachytherapy dose delivery follows the inverse square law with rapid dose fall of leading to minimal damage to the surrounding normal tissue. The safe direct elivery of the radiation dose to the tumour leads to good treatment outcomes comparable to other modalities of treatment. Hence, it is crucial to maintain a harp drop in the radiation dose distribution within very short distances. Treatment planning system (TPS) which is controlled by a computer algorithm plays a significant role in calculating the optimum doses to the tumour area during a typical HDR brachytherapy treatment. However, the optimum dose calculated by the TPS must be verified by using an independent testing method in order to eliminate under/over irradiation of the tumor region and as quality assurance. In general, two types of independent dose verification methods(experimental and computational) are used to crosscheck the doses calculated by TPS. This systematic review aims to summarize the studies done in the past ten years on HDR brachytherapy treatment planning verification and to analyze the reliability and limitations.

Keywords: HDR Brachytherapy Treatment planning system (TPS) Dose calculation Monte-Carlo (MC) simulation Dose verification

Concluzii

Verification of the dose distribution during brachytherapy treatment through an independent method helps to optimize the treatment plan. By using well designed experimental and MC dose verification systems, radiation doses delivered to the patient can be estimated properly. It helps to yield the actual dose received by the patients without any over or under estimations.

Additionally, they provide possibility of QA and specific QC of the brachytherapy treatment. These techniques make the treatment procedure more efficient by obtaining the dose distributions in real-time and actual clinical situations. However, further improvements are required in dose verification methods to cater the rapid developments in clinical and scientific techniques related to brachytherpy treatment.

Articol 2

Lyu Huang, Hani Gaballa, Jenghwa Chang, Evaluating dosimetric accuracy of the 6 MV calibration onEBT3 film in the use of Ir-192 high dose rate brachytherapy, J. Appl. Clin. Med. Phys., 2022;23:e13571, https://doi.org/10.1002/acm2.13571

Abstract

Purpose: To evaluate the dosimetric accuracy of EBT3 film calibrated with a 6 MV beam for high dose rate brachytherapy and propose a novel method for direct film calibration with an Ir-192 source.

Methods: The 6 MV calibration was performed in water on a linear accelerator (linac). The Ir-192 calibration was accomplished by irradiating the film wrapped around a cylinder applicator with an Ir-192 source. All films were scanned 1-day post-irradiation to acquire calibration curves for all three (red, blue, and green) channels. The Ir-192 calibration films were also used for single-dose comparison.

Moreover, an independent test film under a H.A.M. applicator was irradiated and the 2D dose distribution was obtained separately for each calibration using the red channel data. Gamma analysis and point-by-point profile comparison were performed to evaluate the performance of both calibrations. The uncertainty budget for each calibration system was analyzed.

Results: The red channel had the best performance for both calibration systems in the single-dose comparison. We found a significant 4.89% difference from the reference for doses <250 cGy using the 6 MV calibration, while the difference was only 0.87% for doses >600 cGy. Gamma analysis of the 2D dose distribution showed the Ir-192 calibration had a higher passing rate of 91.9% for the 1mm/2% criterion, compared to 83.5% for the 6 MV calibration. Most failing points were in the low-dose region (<200 cGy). The point-by-point profile comparison reported a discrepancy of 2%–3.6% between the Ir-192 and 6 MV calibrations in this low-dose region. The linac- and Ir-192-based dosimetry systems had an uncertainty of 4.1% (k = 2) and 5.66% (k = 2), respectively.

Conclusions: Direct calibration of EBT3 films with an Ir-192 source is feasible and reliable, while the dosimetric accuracy of 6 MV calibration depends on the dose range.The Ir-192 calibration should be used when the measurement dose range is below 250 cGy.

KEYWORDS: EBT3 film, film calibration,HDR brachytherapy, radiochromic film dosimetry

FIGURE 1 Film set-up for the 6 MV and Ir-192 calibrations. (a) Shows the film set-up for the 6 MV calibration. The precut film was fixed on top of a Roos chamber holder attached to an MP1 phantom tank. (b) and (c) Illustrate the Ir-192 calibration. The precut film piece was wrapped around and fixed to a cylinder high dose rate (HDR) applicator of 40mm in diameter. (c) The setup was scanned, and a treatment plan was prepared for calibration with the Ir-192 source

Concluzii

To the best of our knowledge, this is the first work that evaluated the dosimetric accuracy of 6 MV calibration on EBT3 film for Ir-192 HDR brachytherapy in the dose range up to 1000 cGy.We have developed a feasible calibration protocol for direct calibration of the ETB3 film in water with the Ir-192 HDR source and used this protocol as the gold standard to evaluate the dosimetric accuracy of 6 MV calibration. The uncertainty budget analysis showed that the uncertainty is reasonable for both calibrations. Direct calibration using the Ir-192 source has an expanded uncertainty of 5.66%, compared to 4.1% using the 6 MV photon beam. Performance associated with the two (6 MV and Ir-192) calibrations was analyzed by comparing the planned dose distributions of an HDR brachytherapy plan with those measured using EBT3 films calibrated with the two sources. The dosimetric accuracy of 6 MV calibration was found to be inferior only in the low-dose region, for example, below 250 cGy, compared to the direct Ir-192 calibration. Therefore, we concluded that the 6 MV calibration is clinically acceptable, considering the overall uncertainties. The accuracy in low-dose (<250 cGy) regions can be improved by scaling up the dose to around 600 cGy for the 6

MV calibration. When dose scaling is not available, the direct Ir-192 calibration should be performed.

Articol 3

K. Inoue, Y. Watanabe, T. Maeyama, S. Mizukami, S. Hayashi, T. Terazaki, H. Muraishi, T. Gomi, T. Shimono, RSC: Dosimetry in high-dose-rate brachytherapy with a radiofluorogenic gel dosimeter, Journal of Physics: Conference Series 2167 (2022) 012032, IOP Publishing, doi: https://doi.org/10.1088/1742-6596/2167/1/012032

Abstract

Abstract. A nanoclay-based radio-fluorogenic gel (NC-RFG) was used to verify the source position and dose distribution in high-dose-rate (HDR) brachytherapy. The dose response confirmed linearity up to 60 Gy. The source position could be detected with an accuracy of ≤0.3 mm, and the dose distribution near the Ir-192 source showed good agreement with the Monte Carlo simulation. NC-RFG can be expected to be a quality assurance tool suitable for the evaluating the dose distribution in HDR brachytherapy.

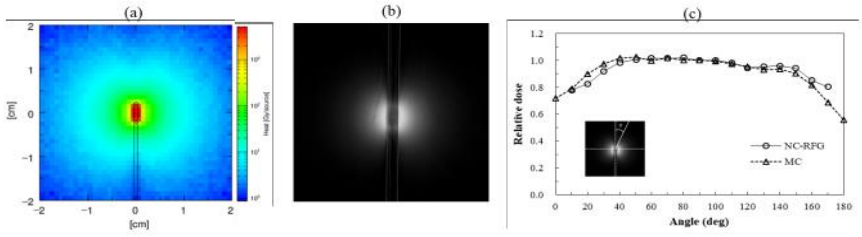

Figure 4. (a) MC calculation and (b) the fluorescence distribution of NC-RFG around a single Ir-192 source. (c) Comparison of the TPS calculations and NC-RFG measurements of gamma rays emitted anisotropically from the center of the Ir-192 source.

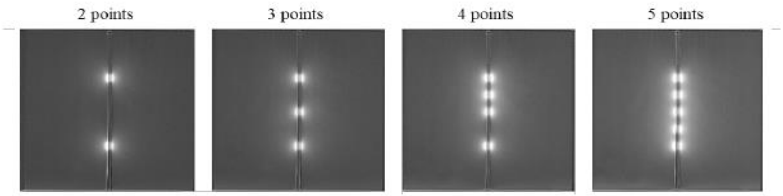

Figure 5. Fluorescence images of NC-RFG irradiated at multiple source positions.

Concluzii

In this study, NC-RFG was used to verify source location and dose distribution in HDR brachytherapy. NC-RFG has proven to be able to respond to the characteristics of HDR brachytherapy, which is a dose distribution with a high dose and a steep dose gradient

Articol 4

Sahithi Madireddy, Amit Verma, Bilikere S. Dwarakanath, Rao VL. Papineni, Technological advancements in brachytherapy of cancer , Physics Open 11 (2022) 100109, https://doi.org/10.1016/j.physo.2022.100109

Abstract

Emerging technological advancements in brachytherapy, when used alone or combined with conventional therapies have improved the therapeutic efficacy, leading to enhanced patient survival. Advancements in the use of various isotopes, delivery methods, incorporation of 3D imaging, and 3D printing, have significantly optimized the treatment planning and increased dose delivery accuracy, achieving high target volume irradiation and low normal tissue exposure. Real-time guidance during the implanting of radiation source into the tumor tissue has shown the promising outcome of brachytherapy. Integration of precise in vivo dosimetry methods have reduced the deviations in the measured dose, and associated operational errors, ensuring brachytherapy is accurate, and delivering more targeted doses over the course of the treatment. The use of new forms of radiation sources such as needles, pellets, tubes, overcomes the risk of source clumping and migration. Personalized applicators, biodegradable brachytherapy systems, injectable radiolabeled thermoresponsive polymers offer yet another promising brachytherapy approaches. Here we describe the recent technological innovations in brachytherapy and discuss various strategies adopted to overcome the associated challenges in preclinical and clinical settings.

Keywords: Brachytherapy Ionizing radiation Dosimetry Survival Cesium Iridium

Concluzii

Brachytherapy is a highly important cancer treatment with the unique ability to deliver high doses of radiation to a very specific location while sparing surrounding tissue, allowing for highly

conformal dose distributions. It is mainly used in prostate cancer, breast cancer, and gynecological cancer, where it may be used alone or as a boost to other forms of radiation therapy. Although brachytherapy can only be used in limited situations, advances in imaging and delivery are increasing the scope and efficacy of this treatment.

Articol 5

Bhagat Chand, Priyamvda, Muninder Kumar, Sangeeta Prasher, Mukesh Kumar, Effect of CT number to relative electron density curves acquired at different tube voltage and current on radiotherapy dose calculation, Journal of Physics: Conference Series 2267 (2022) 012140, IOP Publishing, doi: https://doi.org/10.1088/1742-6596/2267/1/012140

Abstract

Computed tomography (CT) images contain information of relative electron density (RED) of tissues in terms of CT numbers and hence are utilized for tissue inhomogeneity corrections in radiotherapy dose calculations. The present study has determined the effect of tube voltage and current on CT number to RED calibration (CT sensitometry) curves. Catphan phantom containing materials of REDs from 0.001 to 1.868 has been scanned at tube voltage from 80 kV to 140 kV and tube current from 100 to 475 mA. CT numbers of all the materials except Teflon has been found to increase with tube voltage. Variations up to 80 HU has been observed with voltage. Variations with tube current were random. CT numbers changed by higher values at low voltage than at higher voltages. The radiation dose varied by less than 1 % for different curves used for dose

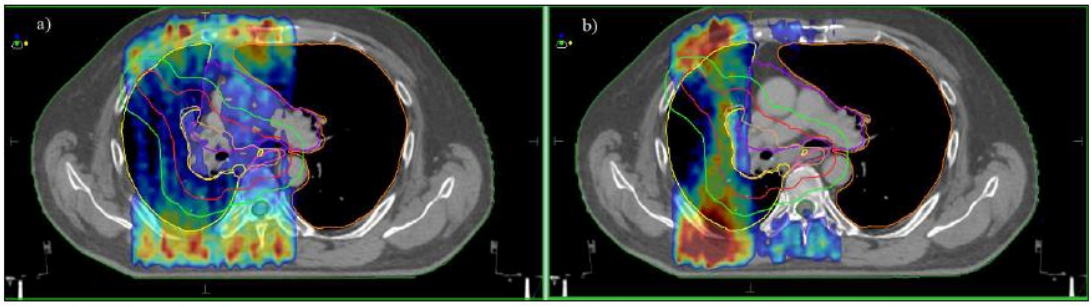

Figure 1. The effect of inhomogeneity correction on the patient dose calculation. The dose calculated using X-ray Voxelised Monte Carlo algorithm. Without inhomogeneity correction dose is same in lungs and soft tissues in the central region (a) and after applying inhomogeneity corrections, more dose can be seen passing through lungs (b). A dose difference of over 6 % has been observed among the two.

calculation in 3DCRT, VMAT and SRT treatment plans of different anatomical sites. Dose differences decreased with increasing plan complexity. Changes in dose distributions near air cavities and bones have been observed. Variations of CT sensitometry has been found to be statistically significant, however, its dosimetric impact was statistically and clinically insignificant.

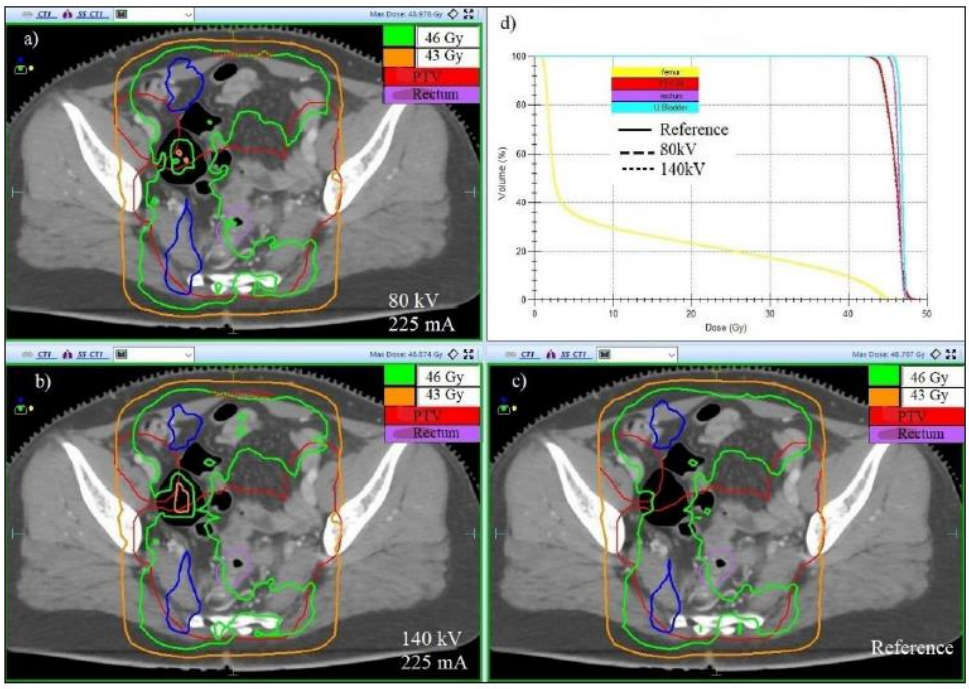

Figure 4. The pelvis CT scan of a patient showing the differences in distribution of 46 Gy and 43 Gy isodose lines at CT to RED curve of 80 kV 225 mA (a), 140 kV, 225 mA (b), reference curve (c) and comparative DVH (d).

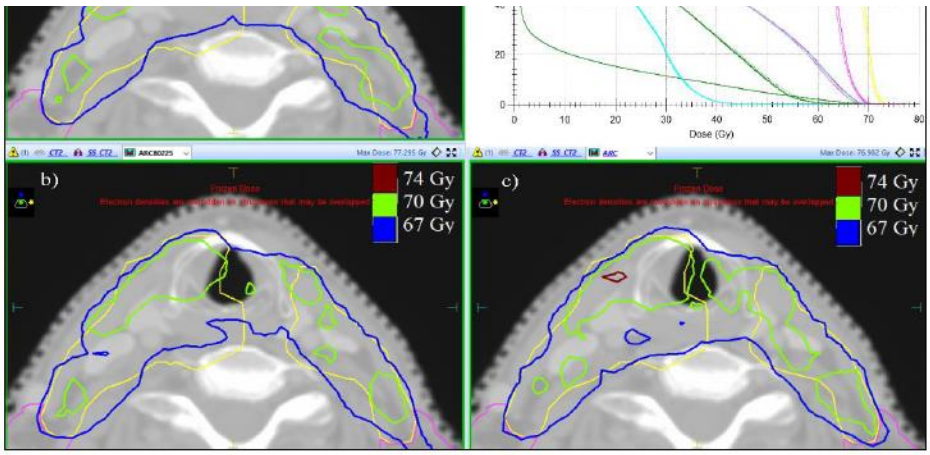

Figure 6. The differences in distribution of 70 Gy isodose in different treatment plans created at CT sensitometry curves of 140 kV 225 mA (a) 80 kV 225 mA (b) reference curve (c) and comparative DVH (d).

Concluzii

The tube currents and voltages have a statistically significant effect on the CT number to RED curves. However, the effect is clinically insignificant. The effect of tube voltage has been more pronounced than tube current with the CT number values increasing with tube voltage for all materials except Teflon. The dosimetric variations in 3DRCT, VMAT and SRT treatment plans has been clinically insignificant as very small variations in plan MU has been observed. The variations in anatomical sites involving air cavities have shown changes in dose distributions at different CT number to RED curves. The present study suggests that the CT sensitometry should be performed for all CT acquisition protocols and effects must be studied. The CT sensitometry curve obtained in the clinic for dedicated CT simulator should be used for radiotherapy dose calculations for most precise and accurate estimation of radiation dose and dose distribution. Moreover, the validation of dose calculated using different curves should be verified against the Monte Carlo simulations to obtain the curve yielding closest approximation of the absorbed dose in the tissue.

Articol 6

Vladimir Feygelman, Kujtim Latifi, Mark Bowers, Kevin Greco, Eduardo G. Moros, Max Isacson, Agnes Angerud, Jimmy Caudell, Maintaining dosimetric quality when switching to a Monte Carlo dose engine for head and neck volumetric-modulated arc therapy planning, J. Appl. Clin. Med. Phys., 2022;23:e13572, https://doi.org/10.1002/acm2.13572

Abstract

Head and neck cancers present challenges in radiation treatment planning due to the large number of critical structures near the target(s) and highly heterogeneous tissue composition. While Monte Carlo (MC) dose calculations currently offer the most accurate approximation of dose deposition in tissue, the switch to MC presents challenges in preserving the parameters of care. The differences in dose-to-tissue were widely discussed in the literature, but mostly in the context of recalculating the existing plans rather than reoptimizing with the MC dose engine. Also, the target dose homogeneity received less attention. We adhere to strict dose homogeneity objectives in clinical practice. In this study, we started with 21 clinical volumetric-modulated arc

therapy (VMAT) plans previously developed in Pinnacle treatment planning system. Those plans were recalculated "as is" with RayStation (RS) MC algorithm and then reoptimized in RS with both collapsed cone (CC) and MC algorithms.

MC statistical uncertainty (0.3%) was selected carefully to balance the dose computation time (1–2 min) with the planning target volume (PTV) dose-volume histogram (DVH) shape approaching that of a "noise-free" calculation. When the hot spot in head and neck MC-based treatment planning is defined as dose to 0.03 cc, it is exceedingly difficult to limit it to 105% of the prescription dose, as we were used to with the CC algorithm. The average hot spot after optimization and calculation with RS MC was statistically significantly higher compared to Pinnacle and RS CC algorithms by 1.2 and 1.0 %, respectively. The 95% confidence interval (CI) observed in this study suggests that in most cases a hot spot of ≤107% is achievable. Compared to the 95% CI for the previous clinical plans recalculated with RS MC "as is" (upper limit 108%), in real terms this result is at least as good or better than the historic plans.

Concluzii

When the hot spot in HN MC-based treatment planning is defined at the *D*0.03cc level, it is exceedingly difficult to consistently limit it to 105% of the prescription dose, as we were used to with the CC convolution algorithm. The average calculated hot spot after optimization and calculation with RS MC was statistically significantly higher compared to Pinnacle and RS CC algorithms by 1.2 and 1.0 %, respectively. Only a very small portion of this difference can be attributed to the statistical blurring of the target DVH. The 95% CI observed in this study suggests, however, that in most cases a hot spot of ≤107% is achievable. Compared to the 95% CI for the previous clinical plans recalculated with RS MC "as is"(upper limit 108%),in real terms this result is at least as good or better than the previous plans. It is feasible to transition to the presumably more accurate algorithm without sacrificing realistic target dose homogeneity. The difference in dose-to-bone was less than for other reported combination

of Type B and C algorithms. The dose to soft tissue was essentially unaffected. When making a clinical transition, there is no generic "Type B to C" dosimetric recipe and the effect of the underlying algorithms and implementations need to be examined in detail.

Articol 7

Brian Bismack, Jennifer Dolan, Eric Laugeman, Anant Gopal, Ning Wen, Indrin Chetty,

Model refinement increases confidence levels and clinical agreement when commissioning a three-dimensional secondary dose calculation system, J. Appl. Clin. Med. Phys., 2022;23:e13590, https://doi.org/10.1002/acm2.13590

Abstract

Purpose: Evaluate custom beam models for a second check dose calculation system using statistically verifiable passing criteria for film analysis, DVH, and 3D gamma metrics.

Methods: Custom beam models for nine linear accelerators for the Sun Nuclear Dose Calculator algorithm (SDC,Sun Nuclear) were evaluated using the AAPMTG119 test suite (5 Intensity Modulated Radiation Therapy (IMRT) and 5 Volumetric Modulated Arc Therapy (VMAT) plans) and a set of linical plans.Where deemed necessary, adjustments to Multileaf Collimator (MLC) parameters were made to improve results. Comparisons to the Analytic Anisotropic Algorithm (AAA), and gafchromic film measurements were performed. Confidence intervals were set to 95% per TG-119. Film gamma criteria were 3%/3 mm (conventional beams) or 3%/1 mm (Stereotactic Radiosurgery [SRS] beams). Dose distributions in solid water phantom were evaluated based on DVH metrics (e.g., D95, V20) and 3D gamma criteria (3%/3 mm or 3%/1 mm). Film passing rates, 3D gamma passing rates, and DVHmetrics were reported for HD MLCmachines and Millennium MLC Machines.

Results: For HD MLC machines, SDC gamma film agreement was 98.76% ± 2.30% (5.74% CL) for 6FFF/6srs (3%/1 mm), and 99.80% ± 0.32% (0.83% CL) for 6x (3%/3 mm). For Millennium MLC machines, film passing rates were 98.20% ± 3.14% (7.96% CL), 99.52% ± 1.14% (2.71% CL), and 99.69% ± 0.82% (1.91% CL) for 6FFF, 6x, and 10x, respectively. For SDC to AAA comparisons:
HD MLC Linear Accelerators (LINACs); DVH point agreement was 0.97% ± 1.64% (4.18% CL) and 1.05% ± 2.12% (5.20% CL);3D gamma agreement was 99.97% ± 0.14% (0.30% CL) and 100.00% ± 0.02% (0.05% CL), for 6FFF/6srs and 6x, respectively; Millennium MLC LINACs:DVH point agreement
was 0.77% ± 2.40% (5.47% CL), 0.80% ± 3.40% (7.47% CL), and 0.07% ± 2.15% (4.30% CL); 3D gamma agreement was 99.97% ± 0.13% (0.29% CL), 99.97% ± 0.17% (0.36% CL), and 99.99% ± 0.06% (0.12% CL) for 6FFF, 6x, and 10x, respectively.

Conclusion: SDC shows agreement well within TG119 CLs for film and redundant dose calculation comparisons with AAA. In some models (SRS), this was achieved using stricter criteria. TG119

plans can be used to help guidemodel adjustments and to establish clinical baselines for DVH and 3D gamma criteria.

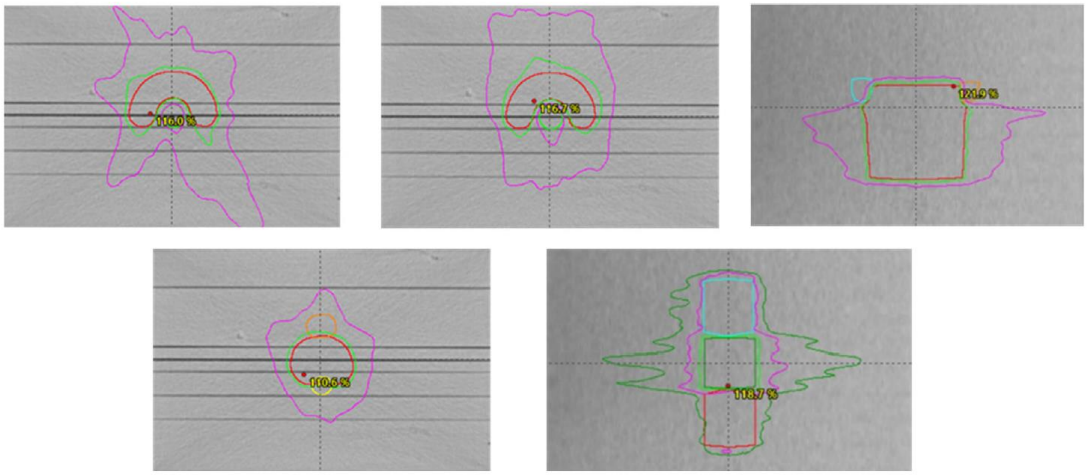

FIGURE 1 Clockwise starting from upper left: easy C-shape (single arc, core contour in green), hard C-shape (2 arc), head and neck (coronal view, parotids in blue and orange), prostate (orange bladder, yellow rectum), and multi-target (dose levels in green, blue, and red in order of dose level). Isodose lines shown are 95% (light green), 50% (magenta), and 30% (dark green) of prescription dose

Concluzii

The Sun Nuclear Dose Check second check package provides 3D comparison tools, such as 3D gamma and DVH point comparisons, allowing for an in-depth means of plan evaluation that was not previously readily available in standard clinics today. The rigor of these comparison tools is bolstered by the sophistication of the CCC algorithm that it employs. This system is a large leap forward over the previous standard of point dose comparisons using effective path length algorithms. However, with this increased complexity also comes an additional burden of rigor of model commissioning and evaluation of clinically significant action levels for the new evaluation tools employed. It has been established in this document that the modeling done by these new 3D second check systems can achieve agreement with measurements within the TG-119 CL. SDC was able to match the primary TPS in digital agreement within parameters outlined by TG-53. In a side-by-side comparison using TG-119 for guidance, SDC showed the capability of matching AAA in agreement with measured film and ion chamber results. Having established that measurements were within TG-119 recommendations, baselines for 3D gamma pass rates (target and OAR) and DVH statistics were gathered from the solid water plans employed by TG-119 and were used to inform clinically relevant action levels.

Articol 8

Honglai Zhang, Lin Wang, Adam C. Riegel, Jeffrey Antone, Louis Potters, Lucille Lee, Yijian Cao, Biological effective dose in analysis of rectal dose in prostate cancer patients who underwent a combination therapy of VMAT and LDR with hydrogel spacer insertion, J. Appl. Clin. Med. Phys., 2022;23:e13584, https://doi.org/10.1002/acm2.13584

Abstract

This study aimed to evaluate rectal dose reduction in prostate cancer patients who underwent a combination of volumetric modulated arc therapy (VMAT) and low-dose-rate (LDR) brachytherapy with insertion of hydrogel spacer (SpaceOAR). For this study, 35 patients receiving hydrogel spacer and 30 patients receiving no spacer were retrospectively enrolled. Patient was treated to doses of 45 Gy to the primary tumor site and nodal regions over 25 fractions using VMAT and 100 Gy to the prostate using prostate seed implant (PSI). In VMAT plans of patients with no spacer, mean doses of rectal wall were 43.6, 42.4, 40.1, and 28.8 Gy to the volume of 0.5, 1, 2, and 5 cm3, respectively. In patients with SpaceOAR, average rectal wall doses decreased to 39.0, 36.9, 33.5, and 23.9 Gy to the volume of 0.5, 1, 2, and 5 cm3, respectively ($p < 0.01$). In PSI plans, rectal wall doses were on average 78.5, 60.9, 41.8, and 14.8 Gy to the volume of 0.5,1,2,and 5 cm3, respectively, in patients without spacer. In contrast, the doses decreased to 34.5, 28.4,20.6 ($p < 0.01$),and 8.5 Gy ($p < 0.05$) to rectal wall volume of 0.5, 1, 2,and 5 cm3, respectively, in patient with SpaceOAR. To demonstrate rectal sum dose sparing, dose-biological effective dose (BED) calculation was accomplished in those patients who showed >60% overlap of rectal volumetric doses between VMAT and PSI. In patients with SpaceOAR, average BEDsum was decreased up to 34%, which was 90.1, 78.9, 65.9, and 40.8 Gy to rectal volume of 0.5, 1, 2, and 5 cm3, respectively, in comparison to 137.4, 116.7, 93.0, and 50.2 Gy to the volume of 0.5, 1, 2, and 5 cm3, respectively,

in those with no spacer. Our result suggested a significant reduction of rectal doses in those patients who underwent a combination of VMAT and LDR with hydrogel spacer placement.

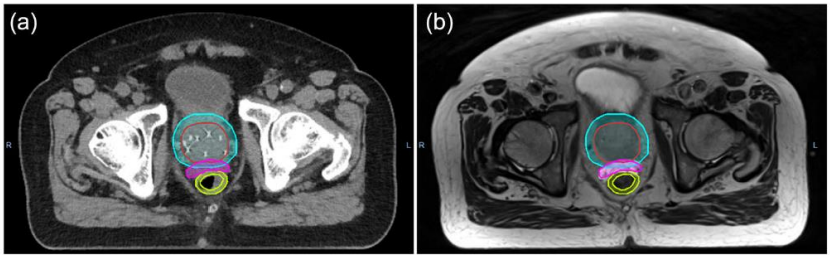

FIGURE 1 An example of computed tomography (CT) (a) and magnetic resonance imaging (MRI) (b). The hydrogel spacer (pink) was inserted between prostate (red) and rectal wall (light green). PTV_{45} (green) was prostate (red) with expansion of the margins.

Concluzii

We concluded that rectal BEDsum calculation would provide valuable information in assessment of dosimetric impact by insertion of hydrogel spacer on rectal sum dose sparing in prostate cancer patients who underwent a combination of EBRT and LDR therapy. Statistically significant dosimetric advantages in rectal wall sparing were observed in favor of patients with hydrogel spacer, indicating up to 34% reduction of rectal wall volumetric dose compared with patients treated without spacer.

This trend held for combined dosimetry as well as EBRT and LDR components.

Articol 9

Zhang Qilin, Bao Peng, Qu Ang, Jiang Weijuan, Jiang Ping, Zhuang Hongqing, Dong Bin, Yang Ruijie, The feasibility study on the generalization of deep learning dose prediction model for volumetric modulated arc therapy of cervical cancer, J Appl Clin Med Phys. 2022;23:e13583, https://doi.org/10.1002/acm2.13583

Abstract

Purpose: To develop a 3D-Unet dose prediction model to predict the threedimensional dose distribution of volumetric modulated arc therapy (VMAT) for cervical cancer and test the dose

prediction performance of the model in endometrial cancer to explore the feasibility of model generalization.

Methods: One hundred and seventeen cases of cervical cancer and 20 cases of endometrial cancer treated with VMAT were used for the model training, validation, and test. The prescribed dose was 50.4 Gy in 28 fractions. Eight independent channels of contoured structures were input to the model, and the dose distribution was used as the output of the model. The 3D-Unet prediction model was trained and validated on the training set (n = 86) and validation set (n = 11), respectively.Then the model was tested on the test set (n = 20) of cervical cancer and endometrial cancer, respectively. The results between clinical dose distribution and predicted dose distribution were compared in the following aspects: (a) the mean absolute error (MAE) within the body, (b) the Dice similarity coefficients (DSCs) under different isodose volumes, (c) the dosimetric indexes including the mean dose (Dmean), the received dose of 2 cm3 (D2cc), the percentage volume of receiving 40 Gy dose of organs-at-risk (V40), planning target volume (PTV) D98%, and homogeneity index (HI), (d) dose–volume histograms (DVHs).

Results: The model can accurately predict the dose distribution of the VMAT plan for cervical cancer and endometrial cancer. The overall average MAE and maximum MAE for cervical cancer were 2.43 ± 3.17% and 3.16 ± 4.01% of the prescribed dose, respectively, and for endometrial cancer were 2.70 ± 3.54% and 3.85 ± 3.11%.The average DSCs under different isodose volumes is above 0.9. The predicted dosimetric indexes and DVHs are equivalent to the clinical dose for both cervical cancer and endometrial cancer,and there is no statistically significant difference.

Conclusion: A 3D-Unet dose prediction model was developed for VMAT of cervical cancer, which can predict the dose distribution accurately for cervical cancer. The model can also be generalized for endometrial cancer with good performance.

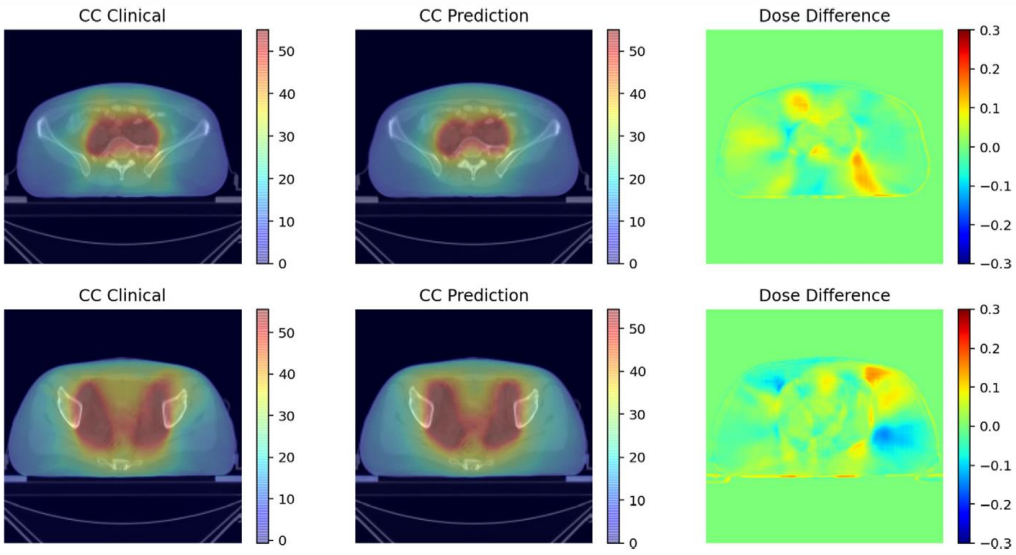

FIGURE 2 The clinical dose distribution map, the model predicted dose distribution map, and the dose difference map at the same slice of the cervical cancer case. The left side is the clinical dose distribution map (the unit is Gy), the middle is the predicted dose distribution map and the right is the dose distribution difference map (take the prescription dose equal to 1 as the standard)

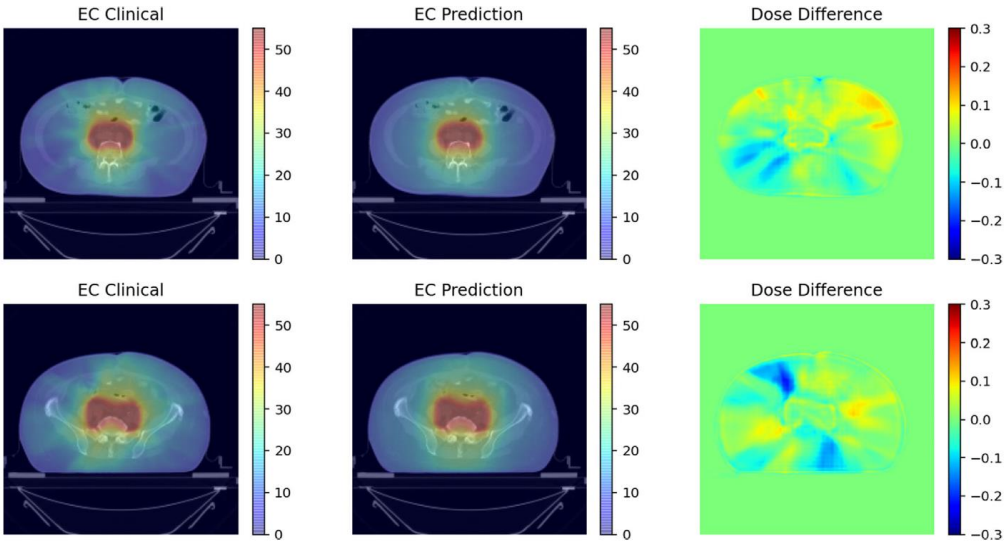

FIGURE 3 The clinical dose distribution map, the model predicted dose distribution map, and the dose difference map at the same slice of the endometrial cancer case. The left side is the clinical dose distribution map (the unit is Gy), the middle is the predicted dose distribution map, and the right is the dose distribution difference map (take the prescription dose equal to 1 as the standard)

Concluzii

A deep learning dose prediction model based on 3Dunet for cervical cancer VMAT plans was developed and evaluated. The model can accurately predict the clinical dose distribution for

cervical cancer. It can also be generalized to endometrial cancer cases with equivalent performance.

Articol 10

James L. Bedford, Ian M. Hanson, A recurrent neural network for rapid detection of delivery errors during real-time portal dosimetry, Physics and Imaging in Radiation Oncology 22 (2022) 36–43, https://doi.org/10.1016/j.phro.2022.03.004

Abstract

Background and purpose: Real-time portal dosimetry compares measured images with predicted images to detect delivery errors as the radiotherapy treatment proceeds. This work aimed to investigate the performance of a recurrent neural network for processing image metrics so as to detect delivery errors as early as possible in the treatment. *Materials and methods:* Volumetric modulated arc therapy (VMAT) plans of six prostate patients were used to generate sequences of predicted portal images. Errors were introduced into the treatment plans and the modified plans were delivered to a water-equivalent phantom. Four different metrics were used to detect errors. These metrics were applied to a threshold-based method to detect the errors as soon as possible during the delivery, and also to a recurrent neural network consisting of four layers. A leave-two-out approach was used to set thresholds and train the neural network then test the resulting systems. *Results:* When using a combination of metrics in conjunction with optimal thresholds, the median segment index at which the errors were detected was 107 out of 180. When using the neural network, the median segment index for error detection was 66 out of 180, with no false positives. The neural network reduced the rate of false negative results from 0.36 to 0.24. *Conclusions:* The recurrent neural network allowed the detection of errors around 30% earlier than when using conventional threshold techniques. By appropriate training of the network, false positive alerts could be prevented, thereby avoiding unnecessary disruption to the patient workflow.

Keywords: In vivo dosimetry Electronic portal imaging device Artificial neural network Volumetric modulated arc therapy

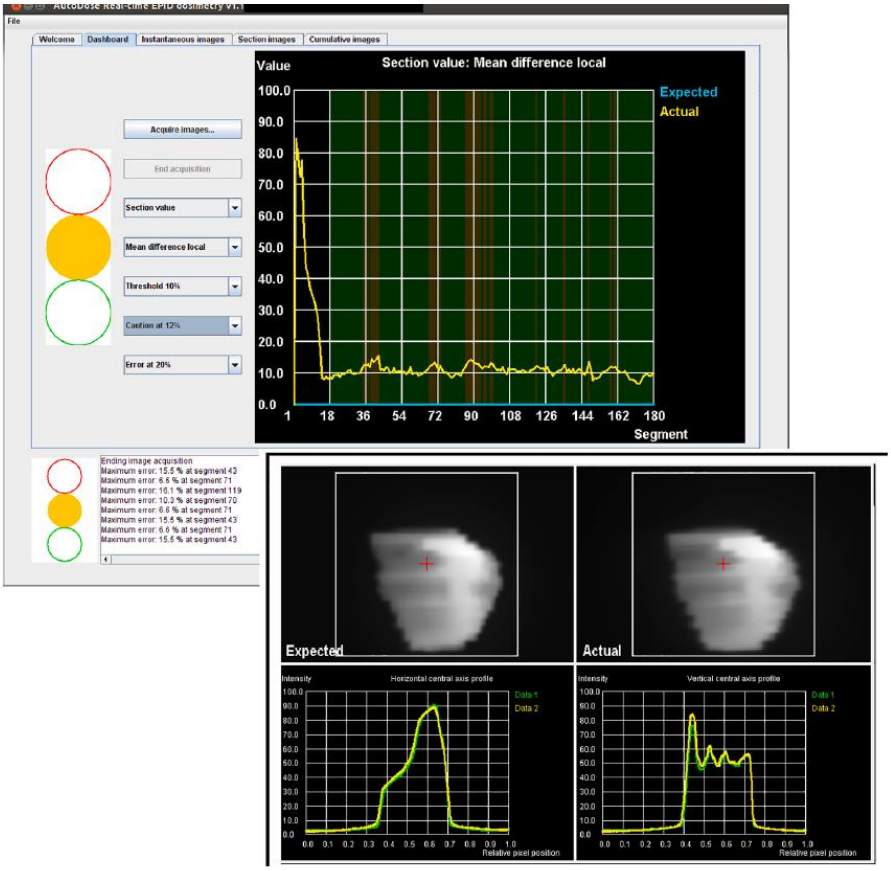

Fig. 1. An analysis of a volumetric modulated arc therapy treatment plan for a patient delivery, seen in AutoDose v1.1. The main panel shows the mean image difference as a percentage of local image intensity for sections of arc consisting of 10 segments. The inset (lower right) shows the expected and actual images for a single section of arc, together with horizontal and vertical profiles through the central axis (Data 1 – expected image, Data 2 – actual image).

Concluzii

Avoidance of false positive results is an important part of this approach, as a false positive error in the real-time context means that the patient's treatment is paused while the error is investigated. False positives also add to the operator workload and encourage a lax attitude towards real errors when they occur. There are some false negative results in the study, mostly for the small error cases where the clinical impact is relatively small, but these are reduced in number by appropriate training of the RNN [50]. A logical progression of this work is use a deep learning approach [30,31,51,52] to analyse the predicted and measured images as a whole. Either the pixels of a difference map between the predicted and measured images, or the pixels of both of the images separately could be applied to the inputs. A convolutional stage could detect specific

image features which might be indicative of errors. The RNN presented in this study, taking as input several measures of difference between predicted and measured images, can be used to provide timely indication of errors during real-time portal dosimetry. In this simulation study of forward-projection portal dosimetry for prostate VMAT, a variety of errors are detected around 30% earlier than when using the image difference measures alone in a threshold-based approach. The leave-two-out strategy used in this feasibility study gives an indication of the benefit likely to be observed in a larger cohort of similarly complex VMAT treatments

Articol 11

Ryohei Miyasaka, SangYong Cho, Takuya Hiraoka, Kohei Chiba, Toru Kawachi, Tetsurou Katayose, Yuhi Suda, Ryusuke Hara, Investigation of Halcyon multi-leaf collimator model in Eclipse treatment planning system: A focus on the VMAT dose calculation with the Acuros XB algorithm, J Appl Clin Med Phys. 2022;23:e13519, https://doi.org/10.1002/acm2.13519

Abstract

Purpose: The dual-layer multi-leaf collimator (MLC) in Halcyon involves further complexities in the dose calculation process, because the leaf-tip transmission varies according to the leaf trailing pattern. For the volumetric modulated arc therapy (VMAT) treatment, the prescribed dose for the target volume can be sensitive to the leaf-tip transmission change. This report evaluates the dosimetric consequence due to the uncertainty of the dual-layer MLC model in Eclipse through the dose verifications for clinical VMAT.Additionally, the Halcyon leaf-tip model is empirically adjusted for the VMAT dose calculation with the Acuros XB.

Materials and methods: For this evaluation,an in-house programthat analyzes the leaf position in each layer was developed. Thirty-two clinical VMAT plans were edited into three leaf sequences:dual layer (original), proximal single layer, or distal single layer. All leaf sequences were verified using Delta4 according to the dose difference (DD) and the global gamma index (GI). To improve the VMAT dose calculation accuracy, the dosimetric leaf gap (DLG) was adjusted to minimize the DD in single-layer leaf sequences.

Results: The mean of DD were −1.35%,−1.20%,and −1.34% in the dual-layer, proximal single-layer, and distal single-layer leaf sequences, respectively. The changes in themean of DD between leaf sequences were within 0.2%.However, the calculated doses differed from the measured doses

by approximately 1% in all leaf sequences. The tuned DLG was increased by 0.8 mm from the original DLG in Eclipse.When the tuned DLG was used in the dose calculation,themean of DD neared 0% and GI with a criterion of 2%/2mmyielded a pass rate of more than 98%.

Conclusion: No significant change was confirmed in the dose calculation accuracy between the leaf sequences. Therefore, it is suggested that the dosimetric consequence due to the leaf trailing was negligibly small in clinical VMAT plans. The DLG tuning for Halcyon can be useful for reducing the dose calculation uncertainties in Eclipse VMAT and required in the commissioning for Acuros XB.

KEYWORDS: Acuros XB, DLG, Halcyon, leaf trailing,VMAT

Concluzii

In the dose verifications for clinical VMAT plans with Halcyon, no significant change was confirmed in the dose calculation accuracy between the dual-layer and the single-layer leaf sequences. Therefore, it is suggested that the dosimetric consequence due to the leaf trailing was insignificant in clinical VMAT plans. However,the original DLG in Eclipse may lead to some systematic discrepancies around ±1% in the dose calculation. In order to improve the Halcyon MLC model in Eclipse TPS, the DLG was tuned specifically for the VMAT dose calculation with the Acuros XB.The DLG that minimized the systematic discrepancies between measured and calculated doses in single-layer leaf sequences was

considered as the DLGemp in this study. The DLGemp was increased by around 0.8 mm from the original DLG in Eclipse. As shown in Figure 7, the dose verification results clearly improved in dual-layer VMAT plans when the DLGemp was used in the dose calculation process.

This result suggests that adjusting the leaf -tip model can be useful for reducing the dose calculation uncertainties and is necessary in the commissioning of Acuros XB for Halcyon.However, Eclipse TPS is not configured to individually assign the DLG value for each MLC layer, and the leaf-trailing effect cannot be modeled. This compromise may make it difficult to tune the DLG value in thestereotactic VMAT plans for the smaller targets.

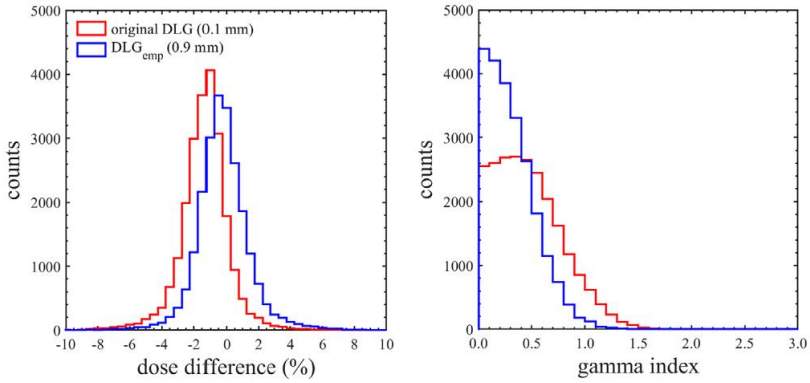

FIGURE 7 The histograms of (a) DD and (b) GI with the criterion of 2%/2 mm calculated with different dosimetric leaf gaps (DLGs; the original DLG of 0.1 mm and the DLG_{emp} of 0.9 mm) for the clinical volumetric modulated arc therapy (VMAT) plans. These histograms are plotted as a sum of VMAT dose verifications, not plan by plan

Articol 12

Igor Olaciregui-Ruiz, Julia-Maria Osinga-Blaettermann, Karen Ortega-Marin, Ben Mijnheer, Anton Mans, Extending in aqua portal dosimetry with dose inhomogeneity conversion maps for accurate patient dose reconstruction in external beam radiotherapy, Physics and Imaging in Radiation Oncology 22 (2022) 20–27, https://doi.org/10.1016/j.phro.2022.04.001

Abstract

Background and purpose: In aqua dosimetry with electronic portal imaging devices (EPIDs) allows for dosimetric treatment verification in external beam radiotherapy by comparing PID-reconstructed dose distributions (EPID_IA) with dose distributions calculated with the teatment planning system in water-equivalent geometries. The main drawback of the method is the inability to estimate the dose delivered to the patient. In this study, an extension to the method is presented to allow for patient dose reconstruction in the presence of inhomogeneities. *Materials and methods:* EPID_IA dose distributions were converted into patient dose distributions (EPID_IA_MC) by applying a 3D dose inhomogeneity conversion, defined as the ratio between patient and water-filled patient dose distributions computed using Monte Carlo calculations. EPID_IA_MC was evaluated against dose distributions calculated with a collapsed cone convolution superposition (CCCS) algorithm and with a GPU-based Monte Carlo dose calculation

platform (GPUMCD) using non-transit EPID measurements of 25 plans. *In vivo* EPID measurements of 20 plans were also analyzed. *Results:* In the evaluation of EPID_IA_MC, the average γ-mean values (2% local/2mm, 50% isodose volume) were 0.70 ± 0.14 (1SD) and 0.66 ± 0.10 (1SD) against CCCS and GPUMCD, respectively. Percentage differences in median dose to the planning target volume were within 3.9% and 2.7%, respectively. The number of *in vivo* dosimetric alerts with EPID_IA_MC was comparable to EPID_IA. *Conclusions:* EPID_IA_MC accommodates accurate patient dose reconstruction for treatment disease sites with significant tissue inhomogeneities within a simple EPID-based direct dose back-projection algorithm, and helps to improve the clinical interpretation of both pre-treatment and *in vivo* dosimetry results.

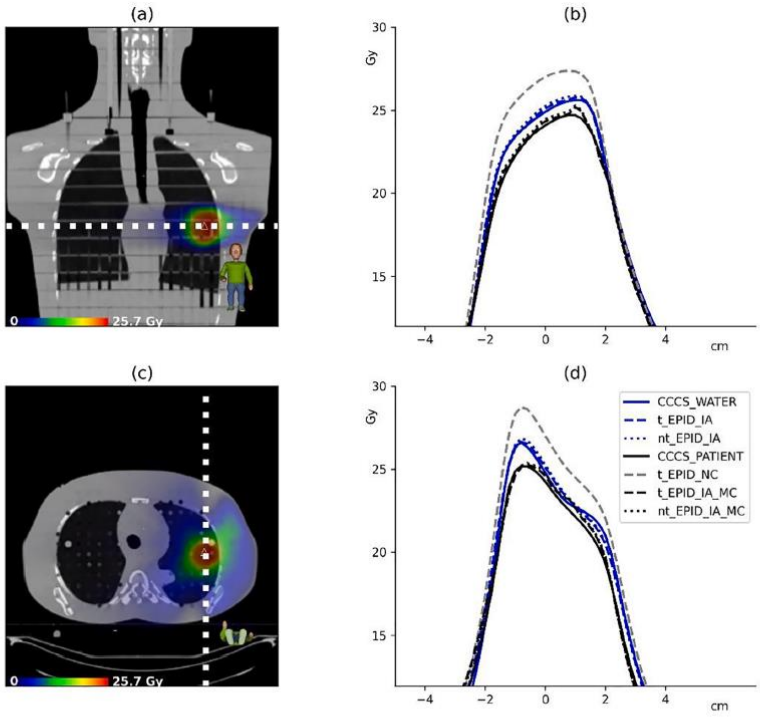

Fig. 2. CT scan of the anthropomorphic (Alderson) phantom and TPS-calculated dose distribution for a double-arc VMAT lung plan in (a) coronal view and (c) axial view, dose profiles through the isocentre in the (b) left–right and (d) anterior-posterior directions. EPID dose reconstructions were performed in three back-projection modes: without corrections (EPID_NC), *in aqua* (EPID_IA) and *in aqua* combined with Monte Carlo dose inhomogeneities conversion maps determined with Scimoca dose calculations (EPID_IA_MC). nt_EPID and t_EPID refer to non-transit and transit EPID dosimetry, respectively. CCCS_PATIENT and CCCS_WATER refer to dose calculations performed with a collapsed cone convolution superposition algorithm for the patient and water-filled patient geometries, respectively.

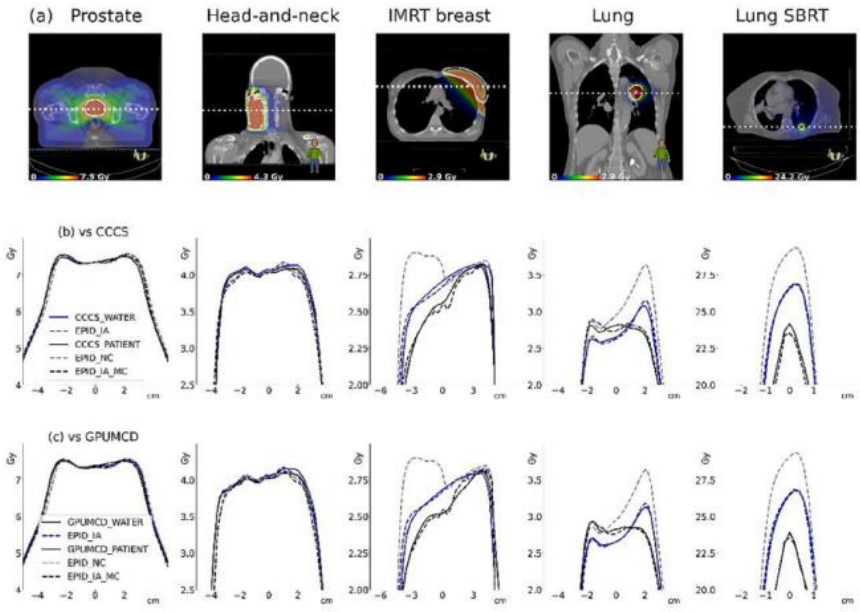

Fig. 3. (a) TPS-calculated dose distributions for five plans of different treatment disease sites, EPID-reconstructed left–right dose profiles through the center of the PTV compared to dose profiles calculated with (b) a collapsed cone convolution superposition algorithm (CCCS) and with (c) a GPU-based Monte Carlo dose calculation algorithm (GPUMCD). EPID dose reconstructions were performed with non-transit EPID measurements in three back-projection modes: without corrections (EPID_NC), *in aqua* (EPID_IA) and *in aqua* combined with Monte Carlo dose inhomogeneities conversion maps determined with SciMoCa dose calculations (EPID_IA_MC). CCCS_PATIENT and CCCS_WATER refer to dose calculations performed with CCCS for the patient and water-filled patient geometries, respectively. GPUMCD_PATIENT and GPUMCD _WATER refer to dose calculations performed with GPUMCD for the patient and water-filled patient geometries, respectively.

Concluzii

In indirect EPID back-projection methods, the EPID signal is back-projected through the patient model to determine the incident fluence to the patient. This fluence, together with a patient model, is fed into a conventional forward dose engine to calculate the contribution of each EPID image (frame) to the total patient dose distribution. EPID_IA_MC results compare well with indirect back-projection methods. The clear advantage of EPID_IA_MC over indirect methods is the extremely fast direct back-projection calculation times of around 100 ms provided that all inputs to the algorithm that are EPID-independent are recomputed. In a clinical setting, one would expect DICMC to be precomputed automatically, which is essential for a large-scale clinical implementation. In conventional workflows, DICMC would be computed using the reference RT plan and the planning CT. In online adaptive workflows, DICMC would be computed using the online adapted RT plan and the daily CT scan. In conclusion, EPID_IA_MC accommodates accurate patient dose reconstruction for treatment disease sites with significant tissue inhomogeneities within a simple EPID-based direct dose back-projection algorithm, and helps to improve the clinical interpretation of *in vivo* dosimetry results.

Articol 13

Anton Mans, Roel Rozendaal, Tomas Janssen, Eugene Damen, Jochem Kaas, Anke van Mourik, Ben Mijnheer, Reduction of systematic dosimetric uncertainties in volumetric modulated, arc therapy triggered by patient-specific quality assurance, Physics and Imaging in Radiation Oncology 21 (2022) 6–10, https://doi.org/10.1016/j.phro.2022.01.001

Abstract

Background and purpose: Dosimetric patient-Specific Quality Assurance (PSQA) data contain in addition to cases with alerts, many cases without alerts. The aim of this study was to present a procedure to investigate long-term trend analysis of the complete set of PSQA data for the presence of site-specific deviations to reduce underlying systematic dose uncertainties. *Materials and methods:* The procedure started by analysing a large set of prostate Volumetric Modulated Arc Therapy (VMAT) PSQA data obtained by comparing 3D electronic portal image device (EPID)_based *in vivo* dosimetry measurements with dose values predicted by the Treatment

Planning System (TPS). If systematic deviations were present, several actions were required. These included confirmation of these deviations with an independent dose verification system for which a 2D detector array in a phantom was used, and analysing calculated with measured PSQA data, or delivery machine characteristics. Further analysis revealed that the under-dosage correlated with plan complexity and coincided with changes in clinically applied planning techniques. *Results:* Prostate VMAT PSQA data showed an under-dosage gradual increasing to about 2% in 3 years, which was confirmed by the measurements with the 2D detector array in a phantom. The implementation of new beam fits in the TPS led to a reduction of the observed deviations. *Conclusion:* Long-term analysis of site-specific PSQA data is a useful method to monitor incremental changes in a radiotherapy department due to various changes in the treatment planning and delivery of prostate VMAT, and may lead to a reduction of systematic dose uncertainties in complex treatments.

Concluzii

Periodic checks of class solutions, in combination with time-trend analysis, such as the one described in this paper, should be performed to ensure that a class solution still delivers the same plan quality as during its initial introduction. In conclusion, long-term trend analysis and data visualization of PSQA data of VMAT were able to trace site-specific deviations due to incremental technical innovations in a radiotherapy department. Application of this procedure unveiled that it could lead to an improvement of the PSQA results and a reduction of systematic dosimetric uncertainties in VMAT .