

Phantoms / QA

A quality assurance method that utilizes 3D dosimetry and facilitates clinical interpretation

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PURPOSE: To demonstrate a new three-dimensional (3D) quality assurance (QA) method that provides comprehensive dosimetry verification and facilitates evaluation of the clinical significance of QA data acquired in a phantom. Also to apply the method to investigate the dosimetric efficacy of base-of-skull (BOS) intensity-modulated radiotherapy (IMRT) treatment. **METHODS AND MATERIALS:** Two types of IMRT QA verification plans were created for 6 patients who received BOS IMRT. The first plan enabled conventional 2D planar IMRT QA using the Varian portal dosimetry system.

Investigating the reproducibility of a complex multifocal radiosurgery treatment

M Niebanck, T Juang, J Newton, J Adamovics, Z Wang and M Oldham

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Stereotactic radiosurgery has become a widely used technique to treat solid tumors and secondary metastases of the brain. Multiple targets can be simultaneously treated with a single isocenter in order to reduce the set-up time to improve patient comfort and workflow. In this study, a 5-arc multifocal RapidArc treatment was delivered to multiple PRESAGE® dosimeters in order to explore the repeatability of the treatment. The three delivery measurements agreed well with each other, with less than 3% standard deviation of dose in the target. The deliveries also agreed well with the treatment plan, with gamma passing rates greater than 90% (5% dose-difference, and 2 mm distance-to-agreement criteria). The optical-CT PRESAGE® system provided a reproducible measurement for treatment verification, provided measurements were made immediately following treatment.

Investigation of 3D dosimetry for an anthropomorphic spine phantom

R Grant, G Ibbott, J Yang, J Adamovics and D Followill

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A new dosimetry insert for the Radiological Physics Center's spine phantom was designed to hold a specially molded dosimeter. The phantom was irradiated with the traditional insert loaded with radiochromic film and TLD, and then with the new 3D dosimetry insert. A comparison with the calculated dose distribution showed that PRESAGE® dosimeter, as well as the film and TLD system, agreed to within ± 2 mm. Further analysis of the 3D dosimeter, including a measured dose volume

histogram, demonstrated the advantages of 3D dosimetry in a clinical environment.

Evaluation of a clinically intuitive quality assurance method

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There is a pressing need for clinically intuitive quality assurance methods that report metrics of relevance to the likely impact on tumor control of normal tissue injury. This paper presents a preliminary investigation into the accuracy of a novel "transform method" which enables a clinically relevant analysis through dose-volume-histograms (DVHs) and dose overlays on the patient's CT data. The transform method was tested by inducing a series of known mechanical and delivery errors onto simulated 3D dosimetry measurements of six different head-and-neck IMRT treatment plans. Accuracy was then examined through the comparison of the transformed patient dose distributions and the known actual patient dose distributions through dose-volume histograms and normalized dose difference analysis. Through these metrics, the transform method was found to be highly accurate in predicting measured patient dose distributions for these types of errors.

Optimizing Gamma Knife quality control: output factor and 3D gamma analysis using PRESAGE – Poster 95th Annual Meeting ARS – 2013

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Purpose/Objectives: Measuring small collimator output factors for Gamma Knife is notoriously difficult, due to the compact dose distribution, steep dose gradients, detector volume averaging affects, and precise detector positioning. High resolution three dimensional (3D) dosimeters can overcome many of these challenges. The purposes of this study were to: (1) test the accuracy of PRESAGE polymer dosimeters in measuring the 4mm Gamma Knife output factor, and (2) testing the feasibility of using 3D gamma analysis on Gamma Knife dose distributions. **Materials/Methods:** An anthropomorphic Cyberknife stereotactic head phantom was outfitted with a Gamma Knife treatment halo for irradiation in a Gamma Knife Perfexion treatment machine. A water-equivalent plastic insert was machined to hold a 60mm diameter by 90mm tall cylindrical PRESAGE dosimeter (Heuris Pharma, Skillman, NJ) in the skull compartment of the phantom. One 4mm and one 16mm shot (4 Gy at 50%) were delivered to the dosimeter axis spaced apart by 45mm. The PRESAGE dosimeter was readout using the Duke Medium Optical Scanning System (DMOS). PRESAGE data was measured in 0.5mm x 0.5mm x 0.5mm voxels via an optical CT technique. Peak shot dose was measured by averaging the dose centered on each shot in a series of different spherical pixel volumes and extrapolating this curve back to a theoretical zero-sized detector. This unique ability of 3D dosimetry systems helps avoid detector volume averaging issues inherent in diode

and ion chamber detectors. The 4mm output factor was calculated taking the ratio of the 4mm to 16mm peak dose and assuming zero timing errors. The 3D gamma analysis was calculated over a 29mm x 38mm x 58mm rectangular volume surrounding the two shots. 3D gamma analysis was computed using CERR (Washington University, Deasy et al). Results: The 4mm output factor was calculated to be: 0.832 ± 0.004 (95% confidence interval). This result was within 2.1% of manufacturers stated 0.815 4mm output factor. The pass rate on the 3D gamma test was 91.1% using the criteria of 5% dose difference, 1mm distance to agreement (DTA), and zero threshold. The pass rate was <50% when the dose difference was 3%. The results are summarized below

Summary of 3D Gamma Analysis Results

Dose Difference (%)	DTA(mm)	Threshold (% of Peak Dose)	3D Gamma Pass Rate
3	1	0.001	29.4%
3	2	0.001	43.2%
5	1	0.001	91.1%
5	2	0.001	95.7%

Conclusions: PRESAGE/DMOS can accurately measure output factors within a few percent of the expected results and avoids the detector positioning and volume averaging challenges of traditional techniques. 3D gamma analysis is a useful tool in measuring the quality of a delivered Gamma Knife plan. A 90% pass rate on a 3D gamma test using the criteria of 5% dose difference, 1mm DTA, and zero threshold shows promise as a future global quality assurance benchmark to allow inter-institutional comparisons and credentialing.

The effect of motion on IMRT – looking at interplay with 3D measurements

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Six base of skull IMRT treatment plans were delivered to 3D dosimeters within the RPC Head and Neck Phantom for QA verification. Isotropic 2mm 3D data was obtained using the DLOS-PRESAGE system and compared to an Eclipse (Varian) treatment plan. Normalized Dose Distribution pass rates were obtained for a number of criteria. High quality 3D dosimetry data was observed from the DLOS system, illustrated here through colormaps, isodose lines, profiles, and NDD 3D maps. Excellent agreement with the planned dose distributions was also observed with NDD analysis revealing > 90% NDD pass rates [3%,

2mm], noise < 0.5%. This paper focuses on a detailed exploration of the quality and use of 3D dosimetry data obtained with the DLOS-PRESAGE system.

Comprehensive quality assurance for base of skull IMRT

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Six base of skull IMRT treatment plans were delivered to Presage dosimeters within the RPC Head and Neck Phantom for quality assurance (QA) verification. Isotropic 2mm 3D data were acquired by optical-CT scanning with the DLOS system (Duke Large Optical-CT Scanner) and compared to the Eclipse (Varian) treatment plan. Normalized Dose Distribution (NDD) pass rates were obtained for a number of criteria. High quality 3D dosimetry data was observed from the DLOS system, illustrated here through color maps, isodose lines, and profiles. Excellent agreement with the planned dose distributions was also observed with NDD analysis revealing > 90% pass rates (with criteria 3%, 2mm), and noise < 0.5%. The results comprehensively confirm the high accuracy of base-of-skull IMRT treatment in our clinic.

Commissioning a CT-compatible LDR tandem and ovoid applicator using Monte Carlo calculation and 3D dosimetry

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Medical Physics (2012), 39(7), 4515-23.

PURPOSE: To determine the geometric and dose attenuation characteristics of a new commercially available CT-compatible LDR tandem and ovoid (T&O) applicator using Monte Carlo calculation and 3D dosimetry. **METHODS:** For geometric characterization, we quantified physical dimensions and investigated a systematic difference found to exist between nominal ovoid angle and the angle at which the afterloading buckets fall within the ovoid. For dosimetric characterization, we determined source attenuation through asymmetric gold shielding in the buckets using Monte Carlo simulations and 3D dosimetry

Toward acquiring comprehensive radiosurgery field commissioning data using the PRESAGE/optical CT 3D dosimetry system

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Physics in Medicine and Biology(2010), 55(5),1279-93.

Achieving accurate small field dosimetry is challenging. This study investigates the utility of a radiochromic plastic PRESAGE read with optical CT for the acquisition of radiosurgery field commissioning data from a Novalis Tx system with a high definition multileaf collimator (HDMLC). Total scatter factors (Sc, p), beam profiles, and penumbrae were measured for five different radiosurgery

fields (5, 10, 20, 30 and 40 mm) using a commercially available optical CT scanner (OCTOPUS, MGS Research). The percent depth dose (PDD), beam profile and penumbra of the 10 mm field were also measured.

Dose verification of stereotactic radiosurgery treatment for trigeminal neuralgia with Presage 3D dosimetry system

Wang, Z.; Thomas, A.; Newton, J.; Ibbott, G.; Deasy, J.; Oldham, M.

Journal of Physics: Conference Series (2010), 250,

Achieving adequate verification and quality-assurance (QA) for radiosurgery treatment of trigeminal-neuralgia (TGN) is particularly challenging because of the combination of very small fields, very high doses, and complex irradiation geometries (multiple gantry and couch combinations). TGN treatments have extreme requirements for dosimetry tools and QA techniques, to ensure adequate verification. In this work we evaluate the potential of Presage/Optical-CT dosimetry system as a tool for the verification of TGN distributions in high-resolution and in 3D. A TGN treatment was planned and delivered

An investigation into the robustness of Optical-CT dosimetry of a radiochromic dosimeter compatible with the RPC Head- and - Neck Phantom

Sakhalkar, H. S.; Adamovics, J.; Ibbott, G.; Oldham, M.

Journal of Physics: Conference Series (2009), 164 .

The potential of the PRESAGE/Optical-CT system as a comprehensive 3D dosimetry tool has been demonstrated. The current study focused on detailed characterization of robustness (intra-dosimeter uniformity and temporal stability) and reproducibility (inter-dosimeter reproducibility) of PRESAGE inserts compatible with the RPC H&N phantom. In addition, the accuracy and precision of PRESAGE dose measurement was also evaluated. Four identical PRESAGE dosimeters (10cm diam. and 7cm height cylinders) were irradiated with the same rotationally sym. treatment plan using a Varian accelerator.

Investigating the feasibility of 3D dosimetry in the RPC IMRT H&N phantom

Sakhalkar, H. S.; Sterling, D.; Adamovics, J.; Ibbott, G.; Oldham, M.

Journal of Physics: Conference Series(2009), 164

An urgent requirement for 3D dosimetry has been recognized because of high failure rate (~25%) in RPC credentialing, which relies on point and 2D dose measurements. Comprehensive 3D dosimetry is likely to resolve more errors and improve IMRT quality assurance. This work presents an investigation of the feasibility of PRESAGE/optical-CT 3D dosimetry in the Radiol. Physics Center (RPC) IMRT H&N phantom. The RPC H&N phantom (with std. and PRESAGE dosimetry inserts alternately) was irradiated with the same IMRT plan. The TLD and EBT film measurement data from std. insert irradiation was provided

Investigation of the feasibility of relative 3D dosimetry in the Radiologic Physics Center Head and Neck IMRT phantom using presage/optical-CT

Sakhalkar Harshad; Sterling David; Adamovics John; Ibbott Geoffrey; Oldham Mark

Medical Physics(2009),36(7),3371-7

This study presents the application of the Presage/optical-CT 3D dosimetry system for relative dosimetry in the Radiologic Physics Center (RPC) Head and Neck (H&N) IMRT phantom. Performance of the system was evaluated by comparison with the "gold-standard" RPC credentialing test. A modified Presage cylindrical insert was created that extended the capability of the RPC H&N phantom to 3D dosimetry. The RPC phantom was taken through the entire treatment planning procedure with both the standard RPC insert and the modified Presage insert. An IMRT plan was created to match the desired dose construct.

An investigation of the accuracy of an IMRT dose distribution using two- and three-dimensional dosimetry techniques

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Medical Physics(2008),35(5),2072-80.

Complex dose delivery techniques like intensity-modulated radiation therapy (IMRT) require dose measurement in three dimensions for comprehensive validation. Previously, we demonstrated the feasibility of the "PRESAGE™/optical-computed tomography (CT)" system for the three-dimensional verification of simple open beam dose distributions where the planning system was known to be accurate. The present work extends this effort and presents the first application of the PRESAGE™/optical-CT system for the verification of a complex IMRT distribution. A highly modulated 11 field IMRT plan was delivered to a cylindrical PRESAGE™ dosimeter (16 cm in diameter and 11 cm in height), and the dose distribution was readout using a commercial scanning-laser optical-CT scanner. Comparisons were made with independent GAFCHROMIC® EBT film measurements, and the calculated dose distribution from a commissioned treatment planning system (ECLIPSE®). Isodose plots, dose profiles, gamma maps, and dose-volume histograms were used to evaluate the agreement. The isodose plots and dose profiles from the PRESAGE™/optical-CT system were in excellent agreement with both the EBT measurements and the ECLIPSE® calculation at all points except within 3 mm of the outer edge of the dosimeter where an edge artifact occurred. Excluding this 3 mm rim, gamma map comparisons show that all three distributions mutually agreed to within a 3% (dose difference) and 3 mm (distance-to-agreement) criteria. A 96% gamma pass ratio was obtained between the PRESAGE™ and ECLIPSE® distributions over the entire volume excluding this rim. In conclusion, for the complex IMRT plan studied, and in the absence of in homogeneities, the ECLIPSE® dose calculation was found to agree with both independent measurements, to within 3%, 3 mm gamma criteria.