Characterization

Investigating the effect of a magnetic field on dose distributions at phantom-air interfaces using PRESAGE® 3D dosimeter and Monte Carlo simulations
Costa, F., Doran, S.J., Hanson, I.M., Nill, S., Billas, I., Shipley, D., Duane, S., Adamovics, J., Oelfke, U.
(2018) Physics in Medicine and Biology, 63 (5), art. no. 05NT0

Dosimetric quality assurance (QA) of the new Elekta Unity (MR-linac) will differ from the QA performed of a conventional linac due to the constant magnetic field, which creates an electron return effect (ERE). In this work we aim to validate PRESAGE® dosimetry in a transverse magnetic field, and assess its use to validate the research version of the Monaco TPS of the MR-linac. Cylindrical samples of PRESAGE® 3D dosimeter separated by an air gap were irradiated with a cobalt-60 unit, while placed between the poles of an electromagnet at 0.5 T and 1.5 T. This set-up was simulated in EGSnrc/Cavity Monte Carlo (MC) code and relative dose distributions were compared with measurements using 1D and 2D gamma criteria of 3% and 1.5 mm. The irradiation conditions were adapted for the MR-linac and compared with Monaco TPS simulations. Measured and EGSnrc/Cavity simulated profiles showed good agreement with a gamma passing rate of 99.9% for 0.5 T and 99.8% for 1.5 T. Measurements on the MR-linac also compared well with Monaco TPS simulations, with a gamma passing rate of 98.4% at 1.5 T. Results demonstrated that PRESAGE® can accurately measure dose and detect the ERE, encouraging its use as a QA tool to validate the Monaco TPS of the MR-linac for clinically relevant dose distributions at tissue-air boundaries.

Investigation of magnetic field effects on the dose–response of 3D dosimeters for magnetic resonance – image guided radiation therapy applications
Lee, H.J., Roed, Y., Venkataraman, S., Carroll, M., Ibbott, G.S.
(2017) Radiotherapy and Oncology, 125 (3), pp. 426-432.

Background and purpose The strong magnetic field of integrated magnetic resonance imaging (MRI) and radiation treatment systems influences secondary electrons resulting in changes in dose deposition in three dimensions. To fill the need for volumetric dose quality assurance, we investigated the effects of strong magnetic fields on 3D dosimeters for MR-image-guided radiation therapy (MR-IGRT) applications. Material and methods There are currently three main categories of 3D dosimeters, and the following were used in this study: radiochromic plastic (PRESAGE®), radiochromic gel (FOX), and polymer gel (BANG™). For the purposes of batch consistency, an

electromagnet was used for same-day irradiations with and without a strong magnetic field (B0, 1.5 T for PRESAGE® and FOX and 1.0 T for BANG™). Results For PRESAGE® the percent difference in optical signal with and without B0 was 1.5% at the spectral peak of 632 nm. For FOX, the optical signal percent difference was 1.6% at 440 nm and 0.5% at 585 nm. For BANG™ the percent difference in R2 MR signal was 0.7%. Conclusions The percent differences in responses with and without strong magnetic fields were minimal for all three 3D dosimeter systems. These 3D dosimeters therefore can be applied to MR-IGRT without requiring a correction factor.

Development of a 3D remote dosimetry protocol compatible with MRgIMRT
Mein, S., Rankine, L., Adamovics, J., Li, H., Oldham, M.
(2017) Medical Physics, 44 (11), pp. 6018-6028

Purpose: To develop a novel remote 3D dosimetry protocol to verify Magnetic Resonance-guided Radiation Therapy (MRgRT) treatments. The protocol was applied to investigate the accuracy of TG-119 IMRT irradiations delivered by the MRIdian® system (ViewRay®, Oakwood Village, OH, USA) allowing for a 48-hour delay between irradiation at a field institution and subsequent readout at a base institution. Methods: The 3D dosimetry protocol utilizes a novel formulation of PRESAGE® radiochromic dosimeters developed for high postirradiation stability and compatibility with optical-CT readout. Optical-CT readout was performed with an in-house system utilizing telecentric lenses affording high-resolution scanning. The protocol was developed from preparatory experiments to characterize PRESAGE® response in relevant conditions. First, linearity and sensitivity of PRESAGE® dose-response in the presence of a magnetic field was evaluated in a small volume study (4 ml cuvettes) conducted under MRgRT conditions and irradiated with doses 0-15 Gy. Temporal and spatial stability of the dose-response were investigated in large volume studies utilizing large field-of-view (FOV) 2 kg cylindrical PRESAGE® dosimeters. Dosimeters were imaged at t = 1 hr and t = 48 hrs enabling the development of correction terms to model any observed spatial and temporal changes postirradiation. Polynomial correction factors for temporal and spatial changes in PRESAGE® dosimeters (CT and CR respectively) were obtained by numerical fitting to time-point data acquired in six irradiated dosimeters. A remote dosimetry protocol was developed where PRESAGE® change in optical-density (ΔOD) readings at time t = X (the irradiation to return shipment time interval) were corrected back to a convenient standard time t = 1 hr using the CT and CR corrections. This refined protocol was then applied to TG-119 (American Association of Physicists in Medicine, Task Group 119) plan deliveries on the MRIdian® system to evaluate the accuracy of MRgRT in these conditions. Results: In the small volume study, in the

presence of a 0.35 T magnetic field, PRESAGE® was observed to respond linearly (R2 = 0.9996) to Co-60 irradiation at t = 48 hrs postirradiation, within the dose ranges of 0 to 15 Gy, with a sensitivity of 0.0305(±0.003) ΔOD cm-1 Gy-1. In the large volume studies, at t = 1 hr postirradiation, consistent linear response was observed, with average sensitivity of 0.0930 ± 0.002 ΔOD cm-1 Gy-1. However, dosimeters gradually darkened with time (OD< 5% per day). A small radial dependence to the dosimeter sensitivity was measured (< 3% of maximum dose), which is attributed to a spherically symmetric dosimeter artifact arising from exothermic heating legacy in the PRESAGE® polyurethane substrate during curing. When applied to the TG-119 IMRT irradiations, the remote dosimetry protocol (including correction terms) yielded excellent line-profile and 3D gamma agreement for 3%/3 mm, 10% threshold (mean passing rate = 96.6% ± 4.0%). Conclusion: A novel 3D remote dosimetry protocol is introduced for validating off-site dosimetrically complex radiotherapy systems, including MRgRT. The protocol involves correcting for temporal and spatially dependent changes in PRESAGE® radiochromic dosimeters readout by optical-CT. Application of the protocol to TG-119 irradiations enabled verification of MRgRT dose distributions with high resolution.

Three-Dimensional Dosimetric Validation of a Magnetic Resonance Guided Intensity Modulated Radiation Therapy System

Rankine, L.J., Mein, S., Cai, B., Curcuru, A., Juang, T., Miles, D., Mutic, S., Wang, Y., Oldham, M., Li, H.H.

(2017) International Journal of Radiation Oncology Biology Physics, 97 (5), pp. 1095-1104

Purpose To validate the dosimetric accuracy of a commercially available magnetic resonance guided intensity modulated radiation therapy (MRgIMRT) system using a hybrid approach: 3-dimensional (3D) measurements and Monte Carlo calculations. Methods and Materials We used PRESAGE radiochromic plastic dosimeters with remote optical computed tomography readout to perform 3D high-resolution measurements, following a novel remote dosimetry protocol. We followed the intensity modulated radiation therapy commissioning recommendations of American Association of Physicists in Medicine Task Group 119, adapted to incorporate 3D data. Preliminary tests (“AP” and “3D-Bands”) were delivered to 9.5-cm usable diameter cylindrical PRESAGE dosimeters to validate the treatment planning system (TPS) for nonmodulated deliveries; assess the sensitivity, uniformity, and rotational symmetry of the PRESAGE dosimeters; and test the robustness of the remote dosimetry protocol. Following this, 4 clinical MRgIMRT plans (“MultiTarget,” “Prostate,” “Head/Neck,” and “C-Shape”) were measured using 13-cm usable diameter PRESAGE dosimeters. For all plans, 3D-γ (3% or 3 mm global, 10% threshold) passing rates were calculated and 3D-γ maps were examined. Point doses were measured with an IBA-CC01 ionization chamber for validation of absolute dose. Finally, by use of an in-house-developed, GPU-accelerated Monte Carlo algorithm (gPENELOPE), we independently calculated

dose for all 6 Task Group 119 plans and compared against the TPS. Results For PRESAGE measurements, 3D-γ analysis yielded passing rates of 98.7%, 99.2%, 98.5%, 98.0%, 99.2%, and 90.7% for AP, 3D-Bands, MultiTarget, Prostate, Head/Neck, and C-Shape, respectively. Ion chamber measurements were within an average of 0.5% (±1.1%) from the TPS dose. Monte Carlo calculations demonstrated good agreement with the TPS, with a mean 3D-γ passing rate of 98.5% ± 1.9% using a stricter 2%/2-mm criterion. Conclusions We have validated the dosimetric accuracy of a commercial MRgIMRT system using high-resolution 3D techniques. We have demonstrated for the first time that hybrid 3D remote dosimetry is a comprehensive and feasible approach to commissioning MRgIMRT. This may provide better sensitivity in error detection compared with standard 2-dimensional measurements and could be used when implementing complex new magnetic resonance guided radiation therapy technologies.

Two-dimensional scanning of PRESAGE®dosimetry using UV/VIS spectrophotometry and its potential application in radiotherapy

(2016) Biomedical Physics and Engineering Express, 2 (4), art. no. 045009

The purpose of this investigation was to provide a high resolution 2D scanning feasibility study for PRESAGE®dosimeters using UV/VIS spectrophotometry. Previously the light absorbance of PRESAGE®has only been made atasingle point using UV/VIS spectrophotometry. The CLARIOstar microplate reader can operate as a2Dscanning UV/VIS spectrophotometer measuring the light absorbanceat multiple points of a PRESAGE®dosimeter. Water equivalent PRESAGE®dosimeters were fabricated in a rectangular shape and were irradiated with 6and18 MVx-ray beams using a medical linear accelerator. The optical density values of the PRESAGE®dosimeters were measured pre and post-irradiation usingaCLARIOstar microplate reader. Depth dose curves and beam profiles were validated against ionisation chamber measurements. The agreement between the two dose measuring devices is well within experimental uncertainties. This investigation demonstrated that depth dose curves and beam profiles canbemeasured with high resolutionin2Dfor megavoltage x-ray beams with PRESAGE®dosimeters using UV/VIS spectrophotometry. Additionally, one PRESAGE®dosimeter was also fabricated with the inclusion of anin homogeneity to investigate the effect on the dose distribution beyond the inhomogeneity. There is also the potential to extend this method toobtain 3D dosimetry scanning.

Experimental determination of the influence of oxygen on the PRESAGE® dosimeter

Alqathami, M., Blencowe, A., Ibbott, G.

(2016) Physics in Medicine and Biology, 61 (2), pp. 813-824

It is generally accepted that the PRESAGE® radiochromic dosimeter is not sensitive to oxygen, however, this claim has not been supported or verified experimentally. Therefore, the aim of this study was to experimentally determine the potential influence of oxygen on dose sensitivity of the PRESAGE® dosimeter and its reporting system. Batches of PRESAGE® and its radical initiator-leuco dye reporting system were prepared in aerobic and anaerobic conditions. The anaerobic batches were deoxygenated by bubbling nitrogen through the dosimeter precursors or reporting system for 10 min. The dosimeters and reporting systems were prepared in spectrophotometric cuvettes and glass vials, respectively, and were irradiated with 6 MV photons to various radiation doses. Changes in optical density of the dosimeters and reporting system before and after irradiation were measured using a spectrophotometer. The overall results show that oxygen has some influence on the dosimetric characteristics of PRESAGE®, although the radical initiator does appear to oxidize the leucomalachite green even in the presence of oxygen. Deoxygenation of the reporting system leads to an increase in sensitivity to radiation dose by ~30% when compared to the non-deoxygenated system. A minor increase in sensitivity (~5%) was also achieved by deoxygenating the PRESAGE® precursor prior to casting. In addition, dissolved oxygen measurements revealed low levels of dissolved oxygen (0.40 ± 0.04 mg l-1) in the polyurethane precursor used to fabricate the PRESAGE® dosimeters, as compared to water (8.60 ± 0.03 mg l-1) and the reporting system alone (1.30 ± 0.10 mg l-1). The results suggest that the presence of oxygen does not inhibit the radiochromic properties of the PRESAGE® system. However, deoxygenation of the dosimeter precursors prior to casting improves the dosimeters dose sensitivity by ~5%, which might be particularly useful for measuring low radiation doses. Nevertheless, we believe this is not sufficient enough to recommend the deoxygenation of commercial PRESAGE® precursor prior to casting. In addition, there were no observed changes in the dose linearity, absorption spectrum and post-response photofading characteristics of the PRESAGE® under the conditions investigated.

Investigation of magnetic field effects on the dose–response of 3D dosimeters for magnetic resonance – image guided radiation therapy applications. Lee, H.J., Roed, Y., Venkataraman, S., Carroll, M., Ibbott, G.S. Radiotherapy and Oncology 125(3), pp. 426-432 **2017**

Background and purpose The strong magnetic field of integrated magnetic resonance imaging (MRI) and radiation treatment systems influences secondary electrons resulting in changes in dose deposition in three dimensions. To fill the need for volumetric dose

quality assurance, we investigated the effects of strong magnetic fields on 3D dosimeters for MR-image-guided radiation therapy (MR-IGRT) applications. Material and methods There are currently three main categories of 3D dosimeters, and the following were used in this study: radiochromic plastic (PRESAGE®), radiochromic gel (FOX), and polymer gel (BANG™). For the purposes of batch consistency, an electromagnet was used for same-day irradiations with and without a strong magnetic field (B 0 , 1.5 T for PRESAGE® and FOX and 1.0 T for BANG™). Results For PRESAGE® the percent difference in optical signal with and without B 0 was 1.5% at the spectral peak of 632 nm. For FOX, the optical signal percent difference was 1.6% at 440 nm and 0.5% at 585 nm. For BANG™ the percent difference in R 2 MR signal was 0.7%. Conclusions The percent differences in responses with and without strong magnetic fields were minimal for all three 3D dosimeter systems. These 3D dosimeters therefore can be applied to MR-IGRT without requiring a correction factor.

Investigating the effect of a magnetic field on dose distributions at phantom-air interfaces using PRESAGE®3D dosimeter and Monte Carlo simulations . Costa, F., Doran, S.J., Hanson, I.M., (...), Adamovics, J., Oelfke, U. Physics in Medicine and Biology 63(5),05NT01 2018

Dosimetric quality assurance (QA) of the new Elekta Unity (MR-linac) will differ from the QA performed of a conventional linac due to the constant magnetic field, which creates an electron return effect (ERE). In this work we aim to validate PRESAGE ® dosimetry in a transverse magnetic field, and assess its use to validate the research version of the Monaco TPS of the MR-linac. Cylindrical samples of PRESAGE ® 3Ddosimeter separated by an air gap were irradiated with a cobalt-60 unit, while placed between the poles of an electromagnet at 0.5 T and 1.5 T. This set-up was simulated in EGSnrc/Cavity Monte Carlo (MC) code and relative dose distributions were compared with measurements using 1D and 2D gamma criteria of 3% and 1.5 mm. The irradiation conditions were adapted for the MR-linac and compared with Monaco TPS simulations. Measured and EGSnrc/Cavity simulated profiles showed good agreement with a gamma passing rate of 99.9% for 0.5 T and 99.8% for 1.5 T. Measurements on the MR-linac also compared well with Monaco TPS simulations, with a gamma passing rate of 98.4% at 1.5 T. Results demonstrated that PRESAGE ® can accurately measure dose and detect the ERE, encouraging its use as a QA tool to validate the Monaco TPS of the MR-linac for clinically relevant dose distributions at tissue-air boundaries.

Water equivalent PRESAGE® for synchrotron radiation therapy dosimetry: Gagliardi, F.M., Day, L., Poole, C.M., Franich, R.D., Geso, M. Medical Physics 2018. 45(3), pp. 1255-1265

Synchrotron Radiation Therapy techniques are currently being trialed and commissioned at synchrotrons around the world. The patient treatment planning systems (TPS) developed for these treatments use simulated data of the synchrotron x-ray beam to produce the dosimetry in the treatment plan. The purpose of this study was to investigate a water equivalent PRESAGE® dosimeter capable of 3D dosimetry over an energy range suitable for synchrotron x-ray beams. Methods: Water equivalent PRESAGE® dosimeters were fabricated with a radiological effective atomic number similar to water over an energy range of 10 keV to 10 MeV. The dosimeters were irradiated at various energies, scanned using optical CT (OCT) scanning and compared to ion chamber measurements. Percentage depth dose and beam profiles of the synchrotron beam were compared to Monte Carlo (MC) model simulations. Results: The PDD profiles of the water equivalent PRESAGE® agreed with ion chamber measurements and MC calculations within 2% for all keV energies investigated. The PRESAGE® also showed good agreement to the MC model for depths below 5 mm of the synchrotron beam where ion chamber data do not exist. The spatial resolution of the OCT was not sufficient to accurately measure the penumbra of the synchrotron beams compared to MC calculations or EBT3 film; however, the water equivalent PRESAGE® was able to verify dose profile characteristics of the MC model. Conclusions: The radiological response of a water equivalent PRESAGE® dosimeter has been validated for synchrotron x-ray beam energies along with the ability to independently verify dose distributions of a MC model.

Water equivalence evaluation of PRESAGE formulations for megavoltage electron beams: a Monte Carlo study

Tina Gorjiara • Zdenka Kuncic • Robin Hill •John Adamovics • Clive Baldock
Australas Phys Eng Sci Med – published on line 09 January 2013 -DOI 10.1007/s13246-012-0174-9

Investigation of radiological properties and water equivalency of PRESAGE dosimeters

Gorjiara, Tina; Hill, Robin; Kuncic, Zdenka; Adamovics, John; Bosi, Stephen; Kim, Jung-Ha; Baldock, Clive
Medical Physics (2011), 38(4), 2265-2274.
Purpose: PRESAGE is a dosimeter made of polyurethane, which is suitable for 3D dosimetry in modern radiation treatment techniques. Since an ideal dosimeter is radiol. water equiv., the authors investigated water equivalency and the radiol. properties of

three different PRESAGE formulations that differ primarily in their elemental compns. Two of the formulations are new and have lower halogen content than the original formulation. Methods: The radiol. water equivalence was assessed by comparing the densities, interaction probabilities, and radiation dosimetry properties.

Dosimetry tools and techniques for IMRT
Daniel A. Low, Jean M. Moran, James F. Dempsey, Lei Dong, and Mark Oldham
Med. Phys. 38, 1313 (2011) **AAPM Task Group 120** update.

Temperature dependence of the dose response for a solid-state radiochromic dosimeter during irradiation and storage
Peter S. Skyt, Jørgen B. B. Petersen, Esben S. Yates and Ludvig P. Muren
Med. Phys. 38 (5), May 2011 p. 2806
Due to the exponential dependencies, stabilization of the dosimeter during irradiation at low temperatures (e.g., 5 C) is preferable in clinical use to optimize the accuracy of the dose response. In addition, a low storage temperature is recommended in order to minimize the post-irradiation temporal change in dose response and thereby increase the post-irradiation stability of the dosimeter. The measurements in this study show that if the observed temperature and temporal dependencies are not considered, this could potentially deteriorate the accuracy of the dosimeter.

An investigation into a new re-useable 3D radiochromic dosimetry material, PresageREU
Pierquet, Michael; Thomas, Andrew; Adamovics, John; Oldham, Mark
Journal of Physics: Conference Series (2010), 250
Purpose: To investigate the dosimetric properties of a new Presage formulation which exhibits a reversible color change on exposure to radiation. PresageREU offers the intriguing possibility of the first re-useable 3D dosimetry material. Method and Materials: Small vols. of PresageREU in 1 × 1 × 5cm optical cuvettes were irradiated and re-irradiated under a variety of conditions and times to investigate a range of properties including re-usability, dose-rate dependence, dose sensitivity, temporal response, energy sensitivity, and temp. dependence.

3-D Dosimetric Comparison of IMRT with 2.5 Mm HD120 MLC Using Optical CT Based Polymer Gel and PRESAGE Dosimeters
Med. Phys. 37, 3232 (2010) SU-GG-T-208
C Wuu, Y Xu, M Maryanski, and J Adamovics
Purpose: To evaluate and compare the 3-D dose distributions for IMRT with 2.5 mm HD120 MLC using optical CT based polymer gel and PRESAGE dosimeters. Method and Materials: In this study, a polymer BANG gel dosimeter and a PRESAGE phantom, together with an optical CT scanner, were employed to implement 3-D dose distribution measurements. Both dosimeters, with 15 cm diameter and 14 cm height, were modified to optimal and linear dose-response characteristics. A slice thickness of 2.5 mm without

spacing was used for CT simulation on both the patient and cylindrical phantoms. The Varian Eclipse treatment planning system was used to design the IMRT radiosurgery plan for a patient with a 2.5 cc small brain tumor treated with 6 MV photon beams. To correlate the optical density response with radiation dose, the same batch of gel and PRESAGE phantoms were irradiated with a 16 MeV electron beam to a known dose at the depth of dmax. The optical density at a specific depth and the PDD table of the electron beam can be used to obtain the optical density dose response of the dosimeters. Both phantoms were scanned with 1 mm pixel resolution using a commercial optical CT scanner, OCTOPUS™ (MGS Research Inc., Madison, CT). Results: Both measured dose distributions from gel and PRESAGE and calculated results are in reasonable agreement. However, the isodose lines from the measurements show more variation than those from the calculation, and this trend is more significant for the 2.5 mm MLC. These discrepancies may be partly attributed to the fact that the calculation grid for the planning system is 2.5 mm yet the resolution of gel measurements is 1 mm, as well as the Trilogy TX having a smaller leaf width. Issues and difficulties on 3-D dosimetric comparison will be presented.

Electron dosimetry in the presence of small cavities

Doran, Simon; Thomas, Russell; Hollingdale, Rachel; Adamovics, John; Nisbet, Andrew

Journal of Physics: Conference Series (2010), 250

Tissue in-homogeneities such as bones or air cavities give rise to significant perturbations of dose during electron radiotherapy. While these can be calcd. using a variety of computational methods, accurate exptl. verification has hitherto been difficult. In this study, we used 3-D optical computed tomog. (CT) dosimetry of PRESAGE samples to obtain central-axis depth dose curves and to study the dose distribution around a simple air cavity. Some concerning anomalous results were obtained for the build-up region of the depthdose curve, which are currently under investigation.

Study of dosimetric water equivalency of PRESAGE for megavoltage and kilovoltage x-ray beams

Gorjiara, Tina; Hill, Robin; Kim, Jung-Ha; Kuncic, Zdenka; Adamovics, John; Baldock, Clive

Journal of Physics: Conference Series (2010), 250

PRESAGE is a dosimeter that is suitable for 3D dosimetry. To be used as an ideal dosimeter, however, it should present radiol. water equiv. properties. In this work, we have investigated the radiol. properties of three different PRESAGE formulations. The radiol. water equivalence was assessed by comparing the photon cross sections and radiation dosimetry properties of the three different PRESAGE formulations with the corresponding values for water. Relative depth doses were calcd. using Monte Carlo methods for 75, 125, 180 and 280 kVp and 6 MV x-ray beams.

A quad phantom' film dosimeter for use as a multi planar verification tool for PRESAGE/optical CT

L Stunja, A Thomas, J Adamovics, J Deasy, M Oldham
Journal of Physics: Conference Series (2010),250
To develop and characterize the accuracy and reproducibility of a „quadphantom dosimeter which will serve as an independent verification tool during commissioning of a PRESAGE/optical CT 3D dosimetry system. A 16cm x 12cm cylindrical quad phantom was constructed from four pieces of solid polyurethane mimicking the PRESAGE material. Films were placed and anchored in orthogonal planes and the quad-phantom was fastened tightly together and placed in a water filled Styrofoam container for irradiation. A simple, two field plan consisting of 6x6cm anterior posterior and right lateral 6MV photon beams (400cGy) was delivered three times (fresh films inserted for each) with a Varian Clinac 600C.

A comprehensive evaluation of the PRESAGE/optical-CT 3D dosimetry system
Sakhalkar H S; Adamovics J;,Ibbott G; Oldham M
Medical physics(2009),36(1),71-82.
This work presents extensive investigations to evaluate the robustness (intradosimeter consistency and temporal stability of response), reproducibility, precision, and accuracy of a relatively new 3D dosimetry system comprising a leuco-dye doped plastic 3D dosimeter (PRESAGE) and a commercial optical-CT scanner (OCTOPUS 5x scanner from MGS Research, Inc). Four identical PRESAGE 3D dosimeters were created such that they were compatible with the Radiologic Physics Center (RPC) head-and-neck (H&N) IMRT credentialing phantom. Each dosimeter was irradiated with a rotationally symmetric arrangement.

Radiological properties of the PRESAGE and PAGAT polymer dosimeters
Brown S; Venning A; De Deene Y; Vial P; Oliver L; Adamovics J; Baldock C
Applied radiation and isotopes (2008),66(12),1970-4.
The radiological properties of the PRESAGE and PAGAT polymer dosimeters have been investigated and their water equivalence determined for use in radiotherapy dosimetry. The radiological water equivalence of each of the polymer dosimeters was determined by comparing the photon and electron interaction cross-sections over the 10 keV-20 MeV energy range and by Monte Carlo modelling the depth dose from a linear accelerator using the BEAMnrc software package. PRESAGE was found to have an effective Z-value and mass density approximately 17% and 10% higher than water, respectively. A maximum difference of 85% was discovered in the photoelectric interaction probability curve of PRESAGE when compared to water over the energy range 10-100 keV, partially due to the Z(3) dependence of the photoelectric effect. The mass radiative stopping power ratios and mass scattering power ratios were both found to have less than 9% difference from water. The depth dose for PRESAGE from a 6MV photon beam had an absolute percentage difference to water of less than 2% and

a relative percentage difference of less than 8%. The mass density of PAGAT was found to be 2.6% higher than water due to its high gelatine and monomer concentration. The cross-sectional attenuation and absorption coefficient ratios were found to be within 5% for energies between 10 and 100 keV and within 1% for energies between 100 keV and 20 MeV. The mass collisional stopping power, mass radiative stopping power and mass scattering power ratios were all less than 1% over the energy range studied. The depth dose had an absolute percentage difference to water of less than 1% and a relative percentage difference of less than 2.5%. These results indicate that the PAGAT polymer gel formulation is more radiological water equivalent than the PRESAGE formulation. However, the PRESAGE dosimeter offers some advantages in terms of ease of use and its lack of water equivalence may be overcome with dosimetric correction factors.

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Three-dimensional shaped solid dosimeter and method of use

Adamovics, John A.

U.S. Pat. Appl. Publ.(2007),US20070020793A1 20070125

The invention relates to a solid plastic three-dimensional dosimeter which is useful in treatment planning, optimization of the radiation field, dose verification, dose vali dation, commissioning, and quality assurance of complex radiotherapy procedures. Dosimeters of the invention can be formed in any clin. relevant shape, and contain a reporter leuco dye which forms a colored image upon irradn.

A practical three-dimensional dosimetry system for radiation therapy Guo Pengyi; Adamovics John; Oldham Mark

Medical physics (2006),33(10),3962-72.

There is a pressing need for a practical three-dimensional (3D) dosimetry system, convenient for clinical use, and with the accuracy and resolution to enable comprehensive verification of the complex dose distributions typical of modern radiation therapy. Here we introduce a dosimetry system that can achieve this challenge, consisting of a radiochromic dosimeter (PRESAGE) and a commercial optical computed tomography (CT) scanning system (OCTOPUS). PRESAGE is a transparent material with compelling properties for dosimetry, including insensitivity of the dose response to atmospheric exposure.

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Characterisation of PRESAGE: a new 3-D radiochromic solid polymer dosimeter for ionising radiation

Adamovics, J.; Maryanski, M. J.

Radiation Protection Dosimetry (2006),120(1-4),107-112.

For the past 50 years there has been interest in developing 3-D dosimeters for ionizing radiation. Particular emphasis has been put on those dosimeters that change their optical properties in proportion to the absorbed dose. Many of the dosimeters that have been evaluated have had limitations such aslack of transparency, diffusion of the image of the dose distribution or poor stability of baseline optical density. Many of these performance limitations have been overcome by the development of PRESAGE™, an optically clear polyurethane-based radiochromic 3-D dosimeter. The solid PRESAGE™ dosimeter is formulated with a free radical initiator and a leuco dye and it does not require a container to maintain its shape. The polyurethane matrix is tissue equivalent and prevents the diffusion of the dose distribution image. There is a linear dose–response, which is independent of both photon energy and dose rate. Simple precautions such as preventing long-term exposure to additional ionizing radiation including ultraviolet and controlling storage temperatures prevent the bleaching of the radiochromic response field within the irradiated dosimeter.

Characterization of a new radiochromic three-dimensional dosimeter
Guo P Y; Adamovics J A; Oldham M
Medical Physics (2006),33(5),1338-45.
The development of intensity-modulated radiotherapy (IMRT) has created a clear need for a dosimeter that can accurately and conveniently measure dose distributions in three dimensions to assure treatment quality. PRESAGE is a new three dimensional (3D) dosimetry material consisting of an optically clear polyurethane matrix, containing a leuco dye that exhibits a radiochromic response when exposed to ionizing radiation. A number of potential advantages accrue over other gel dosimeters, including insensitivity to oxygen, radiation induced light absorption contrast rather than scattering response.

Investigation of the dosimetric characteristics of PRESAGE
Guo, Pengyi; Adamovics, John; Oldham, Mark
Journal of Physics: Conference Series (2006),56,207-210.
PRESAGE is a new material that was recently introduced with some potentially advantageous properties for 3-dimensional dosimetry. The fundamental dosimetric characteristics of PRESAGE were studied to det. its potential for dosimetry. A new method designed to enable rapid, accurate and convenient evaluation of any material which has an optical dose-response, and can be formed into columns of precise dimension (e.g. spectrophotornetric cuvettes), was developed. PRESAGE represents a significant step forward in the development towards a truly practical and convenient 3-dimensional dosimetry.

New 3D Radiochromic Solid Polymer Dosimeter From Leuco Dyes and a Transparent Polymeric Matrix
J Adamovics, M. J. Maryanski
Medical physics (2003),30(6) SU-GG-PDS-29

A new type of solid radiochromic 3D polymer dosimeter has been developed . Components include an alkyl diisocyanate prepolymer, a hydroxy reactive polyol along with a catalyst, which polymerize into a optically clear polyurethane. The diisocyanate and polyol are mixed at approximately a 1:1 ratio with relatively low reaction exotherm, which allows the mixing of a wide variety of heat sensitive leucodyes and free radical and/or acid generators into the polymer reaction matrix. The polymer hardens in approximately 48 hours so that no container is needed to support the dosimeter. The leuco dyes in our dosimeters (leucomalachite green) have a maximum absorbance at 633 nm and is therefore compatible with the OCT-OPUS* laser CT research scanners (MGS Research, Inc.,Madison, CT) operating atthe principal He-Ne laser wavelength of 633nm. We have demonstrated that this dosimeter formulation has characteristics required of a reliable dosimetry technique. Samples contained in 30 ml glass vials were irradiated to graded doses of 145 kVp x-rays and optical absorption spectra of the irradiated samples were measured. In one formulation, the sensitivity of the polymer at 633nm was found to be 0.01 cm-1 Gy-1 between 1Gy and 30Gy. The sensitivity can be controlled by changing the proportions of the polymer's components. Additional data on accuracy, stability, dynamic range, sensitivity control, dose rate effects,optical properties and tissue equivalence of the dosimeter will be presented