

Summary of Esben Yates' trip to Columbia (NY), Duke (NC) and Rider University (NJ), November 2008 - funded by the Varian-NACP grant 2008

Motivation:

The development of intensity-modulated radiotherapy 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 dosimetry material consisting of an optically clear polyurethane matrix, containing a leuco dye that exhibits a radiochromic response when exposed to ionizing radiation¹⁻⁸.

Radiation therapy with other particles such as protons and ions is being used at a limited number of oncology centres throughout the world. Particle therapy, however, has many promising properties and is therefore expected to become more widely used. We have established contact to Deutsches Krebsforschungszentrum (DKFZ) in Heidelberg. In collaboration with DKFZ we have measured the optical response of PRESAGE to establish a 3D dosimeter for particle therapy.

Introduction

Modern radiation treatment techniques including intensity modulated radiotherapy IMRT are being widely used in the clinic with the intent to deliver highly conformal dose in three dimensions. Ideally, the commissioning, as well as routine quality-assurance (QA), of these sophisticated treatment techniques requires a dosimeter that can accurately and conveniently measure dose distribution in three dimensions. IMRT QA dosimetry systems in common use at the present time (e.g., MapCheck2 and RIT3) perform only a limited 2D dose measurement in practice. A critical need has therefore arisen for an accurate and convenient 3D dosimetry system that can more effectively and comprehensively commission and perform routine QA for these techniques. Gel dosimetry has been shown to have promising capability for 3D dose measurement. Typically, in gel dosimetry studies, a macroscopic volume (e.g., 500 ml) of radiation sensitive gel records the 3D dose distribution, which is subsequently read out by MRI, optical-CT, or x-ray CT. Fricke gel and polymer gel are the most popular gel dosimeters reported in literature, and each has merits and limitations. In general, Fricke gel has high reproducibility, and can be easily prepared, but suffers diffusion problems. Polymer gels are relatively stable, with high sensitivity to radiation, but are susceptible to light scattering artifacts and are difficult to prepare as the dose response is sensitive to the presence of free oxygen. Although continual improvements in gel formulations have been reported a new 3D dosimetry material that overcomes these problems is of significant interest. The purpose of this trip was to meet with inventor of PRESAGE and the researchers that have presented the basic characterization of PRESAGE that is designed for use with optical CT. This method has the advantages of high resolution, relatively low noise, and potentially low cost compared with MRI or x-ray CT readout. The composition of PRESAGE is based on a clear polyurethane matrix doped with radiochromic components (leuco dyes) that generate a colour change, and hence optical absorption or optical density (OD) change, on exposure to ionizing radiation. cursory observations indicate a number of attractive features and potential advantages over other gel dosimeters. First, PRESAGE is robust in a lab environment, being insensitive to the atmosphere, and not requiring an external container or phantom material. In addition, the radiochromic colour change absorbs light rather than scatters light, which facilitates high accuracy readout by optical CT. Scatter artifacts have been observed in optical-CT scanning of polymer gels, where the principle mechanism of optical contrast is scatter. Optical-CT images are further enhanced by the lack of a container minimizing the refractive index matching problem and enabling an accurate measurement closer to the periphery of the dosimeter. Dose response sensitivity can be

adjusted by changing the proportions of the leuco-dye and initiating agent components. The solid plastic texture of PRESAGE is amenable to machining to a variety of shapes for different applications. The CT number of a variety of PRESAGE formulations was observed to vary between 100–470. This enables the manufacture of phantoms with different density inserts. The dosimeter with a lower CT number (50) is also under investigation.

Research partners

We have established collaboration with John Adamovics at Rider University, New Jersey. John Adamovics is one of the inventors of PRESAGE. This tissue equivalent plastic material is tailor-made to resemble human tissue and can be made in shapes ideal for measuring complex dose distributions. Much of the research that has so far been done on PRESAGE has been carried out in collaboration between Mark Oldham at the Dept. of Radiation Oncology at Duke University and John Adamovics at Rider University. My visit to Rider University included a visit to the manufacturing laboratory as well as talks to Mr. Adamovics of further developments that can be made with PRESAGE. Investigations are being made into the possibility of making a reusable PRESAGE dosimeter. For this purpose the chemical formulation would have to be adjusted in order for the dosimeter to decrease in optical density after irradiation. Prototypes have been made but no results have been published on this potential feature of PRESAGE.

Marek Maryanski is the inventor of the Octopus scanner, a sophisticated optical scanner which is designed and optimized for reading out complex dose distributions. Mr. Maryanski has been working with bang gels and optical CT scanning for many years and has a great number of publications in the field. I met with Marek at Columbia University, NY where an Octopus Scanner is installed. We talked of the latest development of the Octopus Scanner which is being bought by our department in Aarhus. The scanner has developed greater speed since the first model was presented. At present a scan of a full size head and neck phantom can be done in as little as 30 minutes. Earlier scan times were in the range of 8-12 hours. Our department has received a grant from Aarhus University Hospital's foundation for Research equipment which has allowed for the acquisition of the scanner in May 2009.

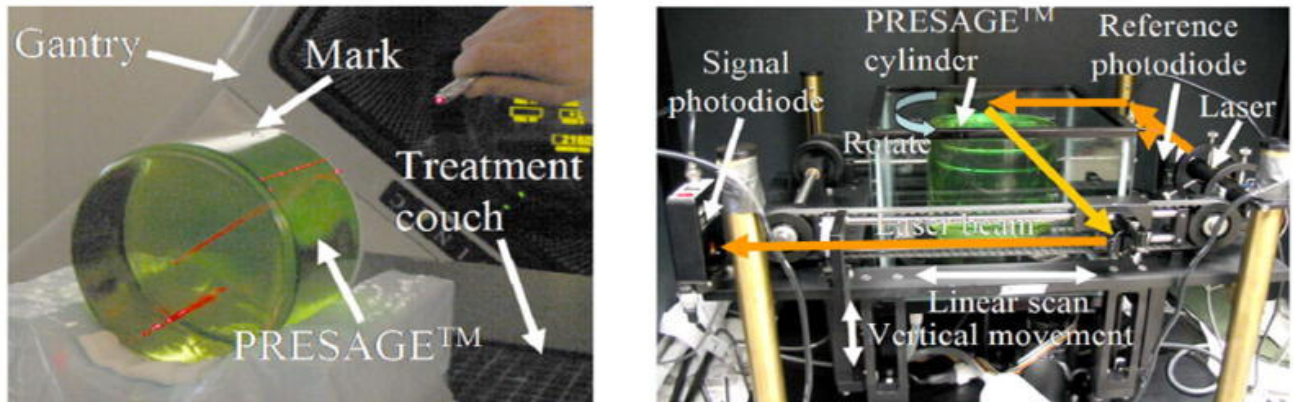


Figure 1: Head and neck PRESAGE phantom on the treatment couch (left) and reading out the optical density change with the PRESAGE scanner (right).

Mark Oldham and his group at Duke University, NC has published several papers together with John Adamovics on dose verification using PRESAGE and the Octopus scanner. Several thorough studies of the reproducibility of PRESAGE samples following IMRT irradiation have been performed here. At Duke there is a full group of scientists working with PRESAGE and 3D dose verification including both postdocs, graduate and Ph. D students. At Duke it is planned to do Rapidarc QA with PRESAGE as the Cancer Clinic at Duke University Hospital South is a Varian Clinic. Mark Oldham has much experience with performing the optical readouts of the PRESAGE samples and was therefore able to give much advice on the subject.

Program for the trip:

Sunday the 26th of October 2008: Billund – Newark International Airport. New York

Tuesday the 28th: Visited Marek Maryanski at Columbia Presbyterian College on the upper Westside of Manhattan.

Thursday the 30th: Visited John Adamovics at Rider University, NJ.

Sunday the 2nd: Travelled to Durham, North Carolina.

Monday the 3rd: Visited Mark Oldham and his group at Duke University.

Tuesday the 4th: Travelled back to Denmark

Outcome of the trip

My visit to Rider University and Duke University has indeed helped the further advancement of PRESAGE and the Octopus scanner as a key modality in Aarhus for complex IMRT 3D dose verification as well as Rapidarc QA. At present we are performing measurements on PRESAGE with carbon ions and MeV photons. The readouts are performed with an optical spectrometer. This readout method does not allow us any spatial information of the dose distribution. These measurements will be possible from May 2009 because of the funding from Aarhus University Hospital and the travel grant from VARIAN NACP.

Acknowledgements:

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