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Digital film dosimetry in radiotherapy and the development of analytical applications software

Yang Wang
University of Wollongong

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DIGITAL FILM DOSIMETRY IN RADIOTHERAPY
and the
DEVELOPMENT OF ANALYTICAL APPLICATIONS SOFTWARE

A thesis submitted in fulfillment of the requirements
for the award of the degree

DOCTOR OF PHILOSOPHY
from the
UNIVERSITY OF WOLLONGONG

By
Yang Wang (BSc, Post GDip)

ENGINEERING PHYSICS

2005

CERTIFICATION

I, Yang Wang, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy, in the Department of Biological Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Yang Wang

31 October 2005

Preface

The clinical imperative

Film dosimetry started being used for radiotherapy quality assurance checks in the 1950s and 1960s. From the 1990s film dosimetry has become an important tool for the dose distribution checks in 3-D conformal radiotherapy and intensity modulated radiotherapy treatment (IMRT). However, film dosimetry results have in the past suffered from large uncertainties. The low accuracy relates to a variety of causes including the film response to radiation beams, dosimetry, and film development and measurement procedures.

The use of film for dosimetry requires the establishment of procedures which minimize the uncertainties in each stage from exposure through development to measurement and analysis.

Digital technique for image optical density calibration

Low cost computer desktop scanners are becoming possibly used for reliable clinical film dosimetry. Desktop transparency scanners, when properly calibrated, provide a reliable and accurate means to measure of film transparency digitally. Both scanner and film response can be linearised to improve the dosimetry analysis results. A software package has been developed to undertake the complex signal analysis and image mapping techniques required for accurate film dosimetry.

Clinical performance of film dosimetry result improvement

The film scanner dynamic range, linearity, gain variations and light source variability must be calibrated before the scanner can be used for dosimetry, the film dosimetry. Perturbations resulting from film processing or image processing are dealt with separately from those arising in digitising.

The film response depends on film type, radiation beam type and energy dependence, phantom buildup, angle of entry and radiation field size. These factors are directly compensated in the film analysis software.

Film dosimetry reliability and accuracy are improved by using this film dosimetry software package.

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Abstract

This study is focused on the analysis, evaluation and calibration of low cost computer desktop scanners for possible use in film dosimetry. The study also includes the development a software package to use the digital output of such scanners for image processing. This software has matured commercially into a suite of programs named **Radiation Oncology Dosimetry Management System (RODOMS)** for use in radiotherapy quality assurance protocols. The input to the software is a bitmap image created by the scanner. The scan signal greyscale value (GSV) is converted into an optical density value (OD) and a calibration is made to the equivalent radiation doses (DOSE). The software functions include:

- Scanner signal calibration – using a standard step wedge film to set and calibrate the dynamic range and scan signal linearity
- OD vs DOSE response curve calibration – using film strips to read the optical density for different dose exposures to establish the OD-DOSE conversion curve.
- Background level uncertainty control – analysis and subtraction of the base + fog value from the film base material and the film over response to radiation scatter.
- Processing noise smoothing – polynomial and mean smoothing, alternately used to reduce the noise caused by film artifacts.
- Beam quality dependence correction – using individual OD-DOSE calibration curves to correct the exposure for a combined beam modality field film dosimetry quality assurance.
- Clinical film dosimetry analysis – graphic user interface (GUI) designed program for radiation field quality assurance in advanced comparison of 3-D and IMRT dose distribution analysis. This includes the IMRT field with the planning computer curve overlaid for a comparative analysis.

Dosimetry phantoms have been designed and used in the testing and evaluation of RODOMS. The software is currently in clinical use in several radiotherapy centers in Australia and Asian countries. The clinical results give

on average a $\pm 3\%$ uncertainty level in most of the clinical cases compared with the ionization or TLD measurement results of up to $\pm 5\%$. By using this software in a variety of clinical situations it is shown in this study that the traditional uncertainty levels in film dosimetry have been significantly reduced.