Calibration of TLD700:LiF for Clinical Radiotherapy Beam Modalities & Verification of a High Dose Rate Brachytherapy Treatment Planning System

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Abbreviations

AAPM	American Association of Medical Physicists in Medicine
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
CI	Confidence Interval
d_{max}	Depth of maximum dose
DVH	Dose volume histogram
EBRT	External Beam Radiotherapy
EC	Electron Capture
FSD	Focus to Surface Distance
HDR	High Dose Rate
HVL	Half Value Layer
IC	Ionisation Chamber
ISL	Inverse Square Law
kVp	peak kilovolts (superficial x ray tube)
LDR	Low Dose Rate
LiF	Lithium Fluoride
Linac	Linear Accelerator
MC	Monte Carlo
MU	Monitor Units
OAR	Organs at Risk
OCP	Oncentra Prostate
PDD	Percentage Depth Dose
PTV	Planned Target Volume
RAH	Royal Adelaide Hospital
SD	Standard Deviation
SSD	Source to Surface Distance
SXR	Superficial X Ray
TCS	Treatment Control System
TG	Task Group
TL	Thermoluminescent
TLD	Thermoluminescent Dosimeter
TPS	Treatment Planning System
US	Ultrasound

I. ABSTRACT

When heated, lithium fluoride (LiF) crystals that have been exposed to ionising radiation emit light proportional to their absorbed dose, in a phenomenon known as thermoluminescence. This phenomenon has applications in dose measurement for radiation research, clinical cancer treatment and personal safety dose monitoring.

LiF thermoluminescent dosimeters (TLDs) have a response that is dependent on the energy spectrum of the incoming radiation. Therefore, TLDs need to be calibrated for each spectrum they are exposed to, in order to be used as accurate dosimeters.

The TLD energy response was investigated specifically for a set of TLD700:LiF(Mg,Ti) chips for a range of clinical radiation beams used for Radiation Oncology treatments, including Linear Accelerator electron and x ray beams, superficial x rays and an ^{192}Ir brachytherapy source. Once calibrated, the TLD chips were used to verify the accuracy of the high dose rate (HDR) brachytherapy treatment planning system, Oncentra Prostate.

To carry out this investigation, the TLD700:LiF chips were exposed to known doses of radiation from nominal 6 MV and 18 MV photon beams as well as nominal 6 MeV, 9 MeV, 12 MeV, 16 MeV and 20 MeV electron beams from a Linear Accelerator. The TLDs were read and the response from each beam was normalised to that from the 6 MV beam. The TLDs were also exposed to a series of known doses from a superficial x ray machine with peak energies of 30 kVp, 40 kVp, 50 kVp, 80 kVp, 100 kVp, 120 kVp and 150 kVp. The response to these was similarly compared to the response from the 6 MV beam with equivalent dose.

The TLDs were then calibrated for exposure to an iridium-192 source, used for HDR brachytherapy. The delivered dose was determined by Monte Carlo simulation of the experimental setup using the package GEANT4. The TLDs were exposed to the source in air and at varying depths in water. The response for each of these scenarios was compared to the response from the 6 MV beam.

Finally, the calibrated TLDs were used to verify the Oncentra Prostate treatment planning system by exposing them within a water phantom. A realistic prostate treatment plan was created on a reconstructed ultrasound image data set of the phantom. The treatment plan was delivered to the phantom with the TLD chips at known locations. The dose to the TLDs was compared to the simulated doses at corresponding points in the phantom within Oncentra Prostate.

Results show that, relative from the response to the 6 MV beam, TLDs under-respond by approximately 4% for electron beams and by approximately 3% for the 18 MV photon beam. An over-response of up to 54% was observed for SXR beams with peak energies between 40 and 150 kV. The TLD700 chips over-respond by approximately 11% when exposed to the gamma spectrum of ^{192}Ir in air and were shown to have a depth dependent response in water.

The TLDs used to verify Oncentra Prostate produced a dose ratio of D_{TLD}/D_{OCP} that was not statistically different from the expected value of 1.0 at the 5% significance level. With confidence level 95%, the true value of D_{TLD}/D_{OCP} was shown to lie in the confidence interval 1.023±0.041. Therefore, Oncentra Prostate was considered verified for the full prostate treatment. When compared directly with Monte Carlo predictions, the dose ratio values of D_{MC}/D_{OCP} were also found not to be statistically different to 1.0 at the 5% significance level for a single dwell treatment plan. With confidence level 95%, the true value of D_{MC}/D_{OCP} was shown to lie in the confidence interval 1.029±0.064, so Oncentra Prostate was also considered verified for the single source dwell treatment plan.

II. DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

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