PhD Thesis Title: Dosimetry of a Miniature X-Ray Source Used in Intraoperative Radiation Therapy

Author: Peter G. F. Watson
Email: peter.watson@mcgill.ca
Institution: McGill University
Supervisor: Dr. Jan Seuntjens
Graduation Date: 31 May 2019
Available Online:
https://search.proquest.com/openview/5c39308670a0a84a3e42dd654483b0bf/1?pq-origsite=gscholar&cbl=44156

ABSTRACT:

The INTRABEAM System (Carl Zeiss Meditech AG, Jena, Germany) is a miniature x-ray source operating at 50 kVp for use in intraoperative radiation therapy (IORT). Electrons are accelerated towards a hemispherical thin gold target to produce a radially isotropic photon intensity distribution, consisting of bremsstrahlung and fluorescence photons. The INTRABEAM source is primarily used to treat breast cancer and has shown to be a viable option when compared to external beam radiation therapy through the results of the TARGIT-A clinical trial.

The x-ray source was modelled using EGSnrc, a Monte Carlo (MC) particle transport code. Source and applicator materials and dimensions were taken from published data and specifications provided by the manufacturer. The simulated spectrum results were compared with previously published simulation and measurement results, and validated with measurements of half-value layer performed in-air, and percent depth dose measurements in a water phantom. The effect of including explicit M– and N–subshell atomic transitions versus averaged shells in the source simulations was investigated and found to be appreciable. The efficiency of using a phase space source of all particles leaving the surface of the INTRABEAM source probe, rather than an electron source striking the gold target was also investigated.

A dose formalism relying on MC-calculated dose ratios was proposed for calculating the absorbed dose to water from the INTRABEAM bare source when measured in a water phantom with an air-kerma calibrated ionization chamber. . It was found that the formalism systematically calculated a larger dose (up to 23% greater) than the equation recommended by the manufacturer. It was determined that the uncertainty in the electrode separation of the PTW 34013 parallel plate ionization chamber used had a significant effect on the dose calculation uncertainty.

The MC-derived formalism (C_Q) and manufacturer recommended (Zeiss) dose determinations were compared with the dose calculation used in the TARGIT protocol as a function of depth in water. Radiochromic film measurements of the absorbed dose were also performed and compared. The dose determined by the C_Q, Zeiss, and film methods generally agreed, when considering measurement uncertainties (5-6%). The TARGIT dose was considerably less than the other methods by 14% to 80%, suggesting that the TARGIT dose underestimates the physical dose to water. The results presented in this work provide strong evidence that the doses delivered in breast IORT treatments following the TARGIT protocol were significantly greater than the dose prescribed, and varied with the size of spherical applicator used.

References to author publications that relate specifically to the dissertation:

1. **Watson, P. G.**, Bekerat, H., Papaconstadopoulos, P., Davis, S., & Seuntjens, J. (2018). "An investigation into the INTRABEAM miniature x-ray source dosimetry using ionization chamber and radiochromic film measurements." Medical Physics, 45(9), 4274-4286. https://doi.org/10.1002/mp.13059

2. **Watson, P. G.**, Popovic, M., & Seuntjens, J. (2017). "Determination of absorbed dose to water from a miniature kilovoltage x-ray source using a parallel-plate ionization chamber." Physics in Medicine & Biology, 63(1), 015016. https://doi.org/10.1088/1361-6560/aa9560.

3. **Watson, P. G.**, & Seuntjens, J. (2016). "Effect of explicit M and N-shell atomic transitions on a low-energy x-ray source." Medical Physics, 43(4), 1760-1763. https://doi.org/10.1118/1.4943954