Abstract

The use of ionizing radiation for treatment of cancer diseases is continuously increasing giving rise to several new questions and concerns. One of the most important aspects of this is the associated dose imparted to healthy tissues. This unwanted dose contribution is a result of both radiotherapy procedures and diagnostic imaging. The dose deposition in healthy tissues from external radiotherapy mainly originates from the incident primary beam. However, the patient also receives non-negligible organ doses originating from secondary radiation produced in the treatment machine and within the patient. This secondary radiation, especially neutrons, can travel large distances and consequently deposit doses to organs located far from the primary treatment field. The dose contribution to healthy organs from diagnostic procedures is growing due to the increase in repeated imaging performed in conjunction with radiotherapy. Also, patients undergoing both external radiotherapy and radionuclide therapy with radioactive isotopes could receive a high combined dose burden to healthy tissues.

The need to quantify the secondary dose contribution and the associated risk of radiation-induced cancer is a relevant matter as new techniques are continuously emerging both in the field of radiotherapy and imaging. The technical advances in modern treatment techniques such as intensity modulated radiotherapy, rotational therapy and ion therapy have contributed to the overall increase in patient survival. A parallel development in medical imaging has caused an increase in the use of cone-beam computed tomography for repeated image-guidance imaging providing better tumor localization and a reduction in high doses deposited in adjacent healthy tissues.

The most accurate way of estimating the risk of radiation-induced secondary cancers is to conduct comprehensive epidemiological studies on an exposed population stretching over several decades. This has been done in the past using cohorts of survivors of the atomic bombings and other nuclear accidents and medical exposures. However, the implementation of these epidemiological data is complex as the types of exposure differ greatly from modern radiotherapy procedures. Also, the long latency associated with radiation-induced secondary cancers further complicate the use of epidemiological data.

Thus, the goal of achieving a dose-response relationship for secondary cancers is not only a matter of assessing the dose to the patient but also on how this data should be analyzed.

Today, the most popular way of achieving this is through theoretical risk models using patient-specific parameters including dose distributions and risk coefficients obtained for populations from epidemiological studies.

Due to the difficulties associated with performing measurements of radiation-induced organ doses from treatment and imaging, the dose is often calculated either analytically using an algorithm employed in the clinical treatment planning system or through Monte Carlo simulations that offer the most accurate tool for such calculations. To allow for accurate Monte Carlo simulations of secondary radiation from external radiotherapy the beam model should be validated against measurements with regard to both the primary beam and the out-of-field secondary radiation.

These aspects have been investigated in individual studies that make the object of the articles included in this thesis. Paper I presents a literature review of secondary doses from different treatment and imaging modalities. Paper II shows a comparison between the risks of radiation-induced cancer for patients treated for head and neck cancer using two different treatment techniques. Paper III deals with Monte Carlo simulations of doses to healthy tissues from radionuclide therapy given in conjunction with external radiotherapy. Paper IV presents the validation of a proton spot scanning Monte Carlo model.