Monte Carlo Calculation of In-air Output Factors

Pang-I Wang[1], Ren-Dih Sheu[2], Uei-Tyng Lin[2], Ching-Jung Lo[3], Chen-Shou Chui [4], Wei-Li Chen[1]

1. National Yang-Ming University, Taipei, TW

2. National Radiation Standard Laboratory, Institute of Nuclear Energy Research, Tao-Yuan, TW

3. Chang Gung Memorial Hospital, Tao-Yuan, TW

4. Memorial Sloan-Kettering Cancer Center, New York, NY

Introduction:

Monte Carlo techniques have been widely used in different areas of medical physics. For example, in radiation therapy, Monte Carlo calculation provides a method to simulate dosimetry. Although computationally intensive and time consuming, Monte Carlo simulation is still an ideal tool for this purpose. In this work, we used Monte Carlo simulations to study the in-air output factors of a clinical photon beam produced by a treatment machine. The variation of in-air output factor with field shape and size is an important problem in radiation therapy and has been studied extensively in the past. For intensity modulated radiation therapy (IMRT), this problem is even more pronounced as each field is composed of many irregularly shaped small fields. We will describe the simulation of the treatment machine, present the results and compare them with measured data, and discuss the limitations of the current method.

Monte Carlo simulation

The Monte Carlo program EGS4 and the user code OMEGA/BEAM were used to simulate the 6 MV photon beam from a Varian 21EX. The component modules we have built for the linac consist of the following: x-ray target (SLABS), primary collimator (CONS3R), Be vacuum window (FLATFILT), flattening filter (FLATFILT), monitor chamber (SLABS), mirror (MIRROR), movable collimator (XYJAWS), clearance (SLABS), and the phantom (CHAMBER). Each simulation used monoenergetic electrons incident on the target. We also used a variance reduction technique “bremsstrahlung splitting” in the electron target region. The cutoff energies for electron and photon transport were 1.489 MeV and 2 MeV, respectively. The bremsstrahlung photons generated by electrons below the cutoff energy were ignored. Each particle is followed until its energy falls below the cutoff energy or it escapes from the system. Energy deposited in the phantom (chamber) was collected for a series of square and rectangular field sizes as defined by the movable jaws.

Experimental methods

The in-air output factors were measured at the isocenter for the same series of square and rectangular fields. These measurements include the effect of backscatter from the collimating jaws into the monitor chamber. In order to separate this effect, another series of measurements was made in a telescopic setting. The chamber was placed at 150 cm surrounded by a lead shield. A 7.5-cm thick lead plate was placed below the machine head to absorb the scattered radiation from the head. A small center hole was drilled in the middle of the plate to allow the primary radiation to go through. These measurements were made for a series of rectangular fields with one set of the jaws fixed at 40 cm while the other set of jaws varied from 3 cm to 40 cm. All measurements were taken on a Varian 21EX with a 6 MV photon beam.

Results and discussion:

As the irradiated field size increases, the in-air output factor also raises. This variation of output factor with the field geometry is attributed to two factors. The primary reason is due to the radiation scattered from the components in the accelerator head. The secondary reason is due to the backscattered radiation into the monitor ionization chamber. Our current implementation of the Monte Carlo method simulated the head scatter very accurately. However, it did not simulate the backscattering into the monitor chamber. Thus, for fair comparison, our Monte Carlo results were compared to the measured data with the monitor backscatter effect removed. Under these conditions, the calculated data agreed with the measured values to less than 1% for symmetric square field sizes from 5 cm to 40 cm. For rectangular fields with a set of the jaws fixed at 40 cm and the other set of jaws varying from 5 cm to 40 cm, the average difference between measured and calculated output factors was within 1%.

Conclusion:

The Monte Carlo technique can be used to simulate the machine head and accurately calculate the in-air output factor for different field sizes as defined by the jaws. Our current implementation, however, did not account for the effect of backscattered radiation into the monitor chamber. This feature can be included in future refinement of the method.