A PROGRAM FOR MONITOR UNIT CALCULATION FOR HIGH ENERGY PHOTON BEAMS IN ISOCENTRIC CONDITION BASED ON MEASURED DATA

N. Gesheva-Atanasova ,
Department of Clinical Dosimetry and Radiation Protection,
National Hospital of Oncology, Sofia

I. Background and purpose:

Accurate dose calculation and dose delivery is essential for the success of radiotherapy. Commercial available, model based treatment planning systems (TPS), are routinely used for monitor unit (MU) calculation. Some of the radiation accidents in the last years which occurred with the patients undergoing radiotherapy, were related to incorrect operation of the planning systems and erroneous monitor unit calculations. In such cases an independent check of the TPS computations is of great importance to prevent errors in the dose calculation for patient treatment.

Nowadays, there are commercial programs for back up MU calculation, based on published or calculated data for the different types of therapy machines. The problem how to verify the output data from such software and to confide in published data was the reason for the decision to create our database.

The aim of this study was:

- to propose a procedure and a program for monitor unit calculation for radiation therapy with high energy photon beams, based on our measured data;
- to compare our data with published data
- to evaluate the precision of the MU calculation program.

II. Material and methods:

The measurements were performed using linear accelerator PRIMUS HE-Siemens operating at energies of 6MV and 18MV Xrays, in isocentric conditions, for regular and wedged beams.

The measurement steps of the absolute dose ($\dot{D}_R$) were performed according to the IAEA's TRS-398 protocol [1], using Unidos dosimeter, equipped with Farmer type ionization chamber, which was calibrated for absorbed dose in water using ^{60}Co - γ rays. The beam quality index (QI) – tissue-phantom ratio *($TPR_{20/10}$)* was measured for all beam qualities. The calibration was performed in reference conditions, at a depth of 10cm, in a large water phantom. The same calibration values were used as input data into the TPSs in our hospital.

A. Head scatter correction factor - $O_0(c_e)$.

The head scatter factor, $O_0(c_e)$ is the output ratio determined at the isocenter for field size c_e, where c_e is the collimator equivalent square for a rectangular collimator setting (X,Y). The measurements were performed in air with an electrometer Unidos and 0.125 cm^3 ion chamber, covered by a home made brass buildup caps, instead in a mini phantom. The buildup caps thickness were calculated and made for our beam qualities. $O_0(c_e)$ was determined for a large range of collimator setting:

— for square collimator setting - 4, 6, 8, 10, 15, 20, 25, 30, 40 cm^2;

— for rectangular fields using two dimensional tables for the above mentioned jaws' positions.

The collimator square equivalent field, c_e for head scatter quantities was derived using a modified Sterling equation, $c_e = (A+1)\times\frac{X\times Y}{X + A\times Y}$ where *A* is the relative weight of the upper collimator jaw - *Y*. The parameter *A* was obtained experimentally, as a value, satisfying the requirement for best polynomial fit of c_e values and $O_0(c_e)$ values.

B. Phantom scatter correction factor - $S_p(s_e)$.

The phantom scatter correction factor, $S_p(s_e)$ for field size s_e is equivalent to the ratio of volume scatter ratios, $\frac{V(z_R, s_e)}{V(z_R, c_R)}$, at reference depth z_R, and it was measured with the same instruments, for the same collimator setting as the head scatter factor, but in a large water phantom. For calculation of the equivalent square field s_e related to the phantom scatter quantities, Sterling equation was applied. A polynomial approximation was found between s_e and $S_p(s_e)$.

C. Tissue phantom ratio -TPR.

For 6 and 18MV energies and for a set of square fields of 4, 6, 8, 10, 15, 20, 25, 30, 40 cm^2, the tissue phantom ratios were determined using MP3 – Automatic Water Phantom System, 0.125cm^3 ion chamber, water sensor and using Mephysto software for TPR measurement.

D. MU calculation program.

For MU calculation program the ESTRO formalism [2] and [3] was used, as well as the main equation for the dose calculation, given by the formula:

$$D(z,c_e) = \dot{D}_R \times MU \times O_0(c_e) \times S_P(s_e) \times TPR(z,s_e).$$

III. Results and discussion:

The parameter, *A*, was determined experimentally for 6MV (QI=0.673), *A*= 0.7175 and for 18MV (QI=0.772), *A*= 0.7021. As the difference between these values was 2%, it was decided to use for both beam qualities the average value *A*= 0.7098. This result was found to be twice smaller then the published data. It is suggested that the reason in this work was the relative weight of the upper jaw, instead of the lower jaw.

The calculation of the polynomial formulas for output ratio, had taken into account the variations in the head scatter. The phantom scatter had been derived by approximating the measured data.

The results obtained for the head scatter correction factor are shown on figures 1 and 2. On these figures the data published in [3] were presented too. The mean value of the differences between measured and calculated values for $O_0(c_e)$ was 0.16% for 6MV and 0.17% for 18MV. The maximum percentage values of the differences were 0.6% and 0.8% respectively. These results demonstrated that the value for parameter *A* described well the collimator exchange effect. For 6MV the differences between presented and published data grow up with field size reaching 0.7% for field size of 40cm^2. The maximum difference for 18MV was 0.5%, observed for field size of 30cm^2.

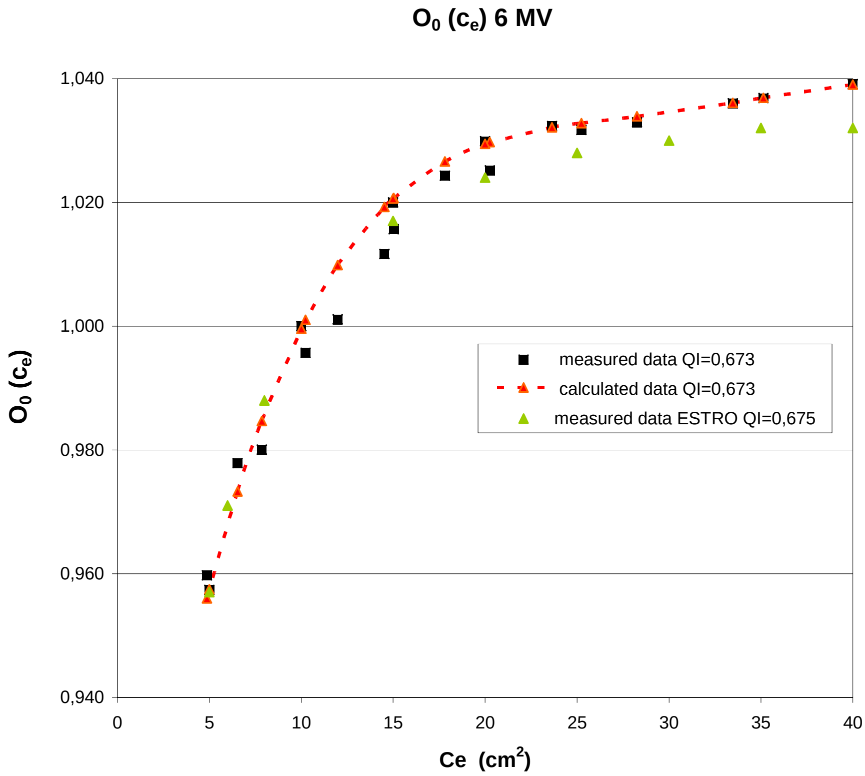

Figure 1. The head scatter factor values (measured, calculated and published by ESTRO), represented as a function of the collimator size, given by its equivalent square field, for 6 MV photon beam quality.

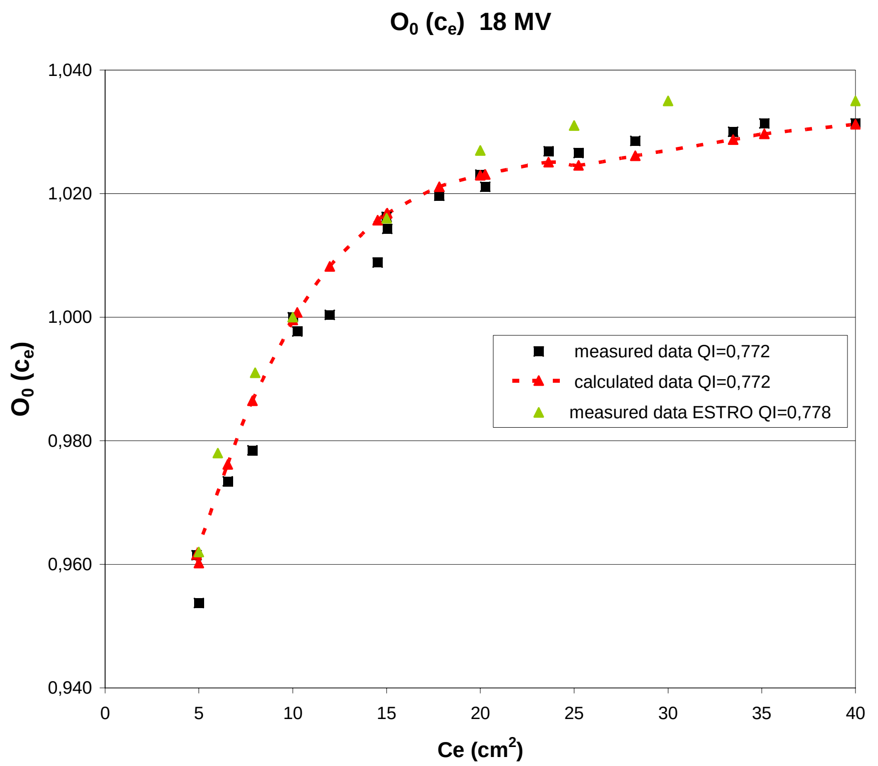

Figure 2. The head scatter factor values (measured, calculated and published by ESTRO), represented as a function of the collimator size, given by its equivalent square field for 18 MV photon beam quality.

The head scatter ratios, measured with brass build-up cap, correspond well to the published results, measured in a mini phantom.

The results for the phantom scatter correction factor $S_p(s_e)$, compared to the published data [3] are given on Figures 3 and 4. The maximum value from the differences between the measured and the calculated data for 6MV and 18MV was 0.4% and the maximum difference compared to the published data was 0.5%.

The TPR values are presented on Figures 5 and 6 only for selected field sizes of 4, 10, 20 and 40 cm^2. The analysis of the results shows that for depths more than 5 cm the measured and the published data coincide in the range of 0.5%, for both beam qualities. For depths less then 5cm and beyond the buildup region, unacceptable deviations reaching 3% for 18MV and up to 2% for 6MV were demonstrated. Within the buildup region (high dose gradient), the measured values showed differences up to 9% and the TPR displacement from the published data has increased up to 8mm.

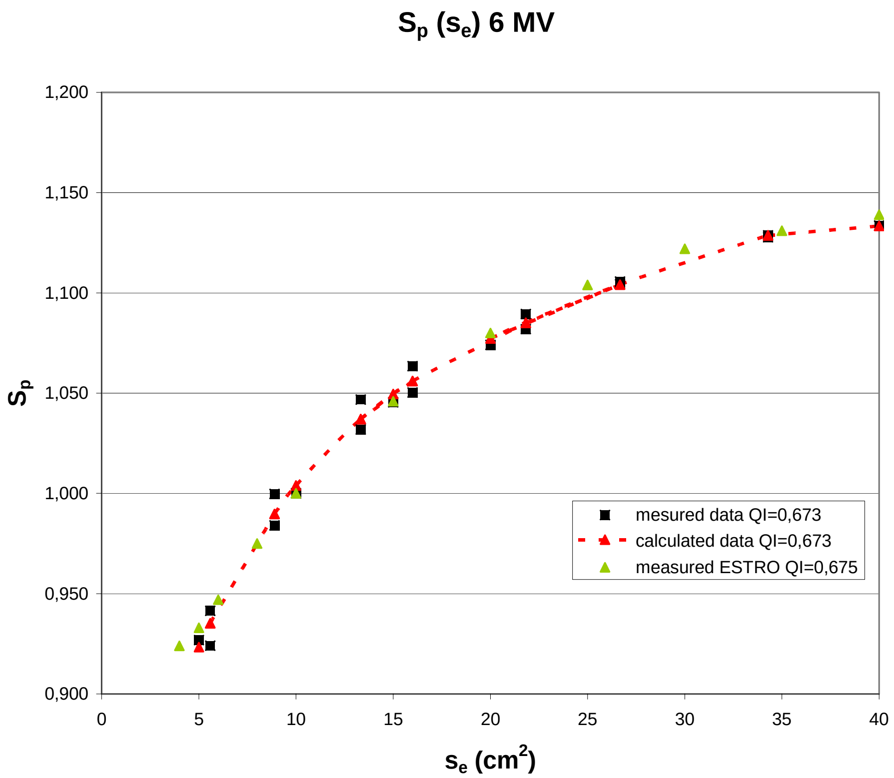

Figure 3. The phantom scatter factor values (measured, calculated and published by ESTRO), represented as a function of the equivalent square field for 6 MV photon beam quality.

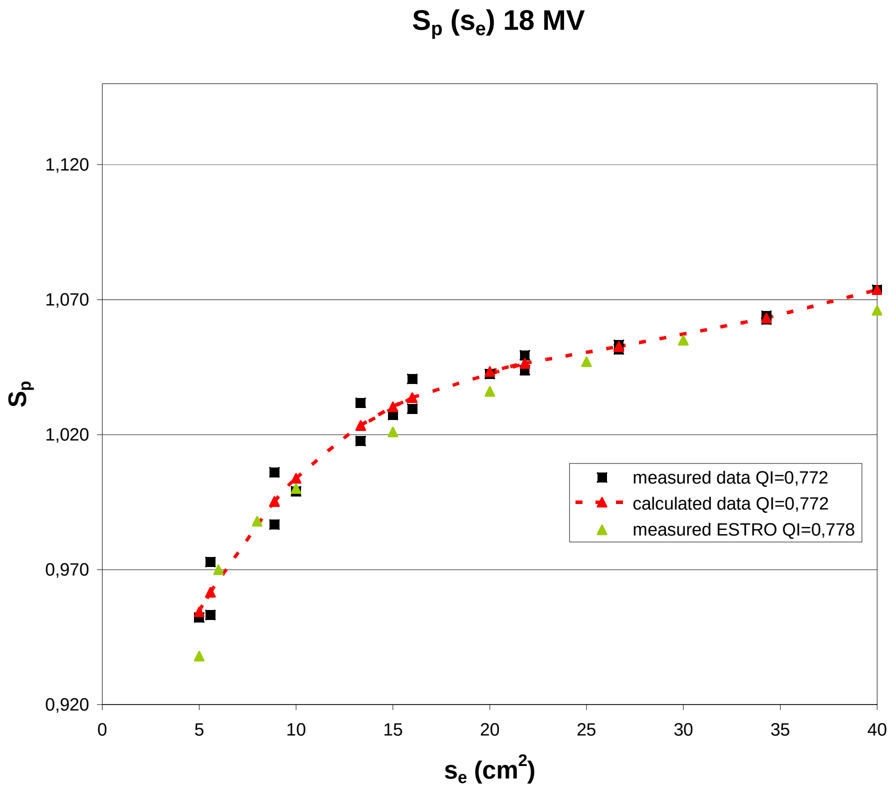

Figure 4. The phantom scatter factor values (measured, calculated and published by ESTRO), represented as a function of the equivalent square field for 18 MV photon beam quality.

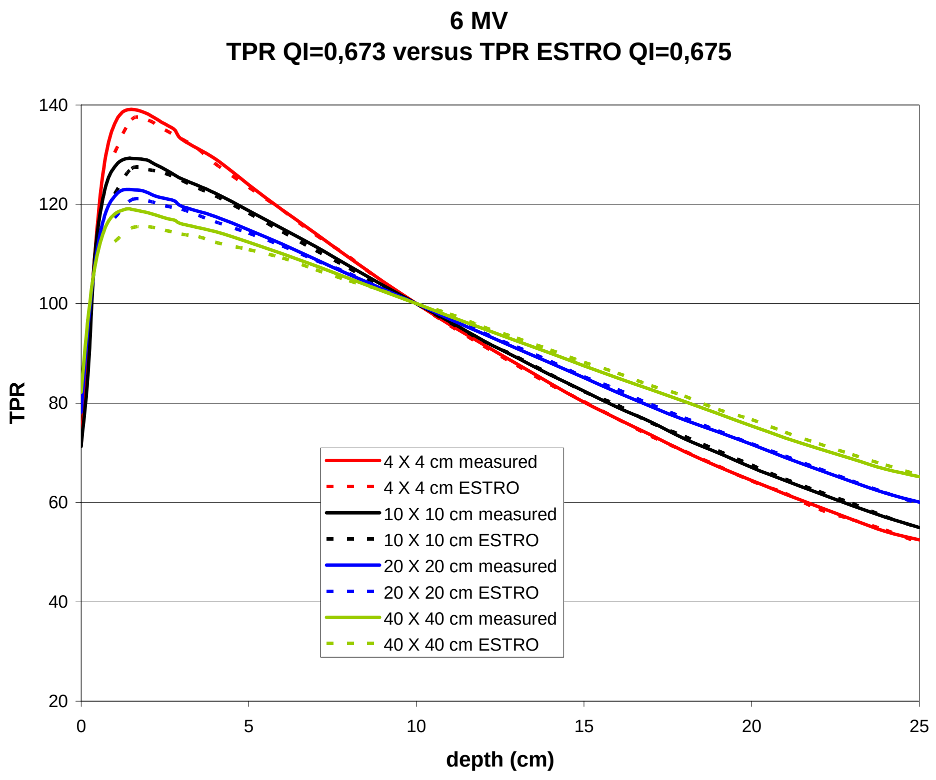

Figure 5. The TPR (measured and published by ESTRO), represented as a function of the depth, for 6 MV photon beam quality.

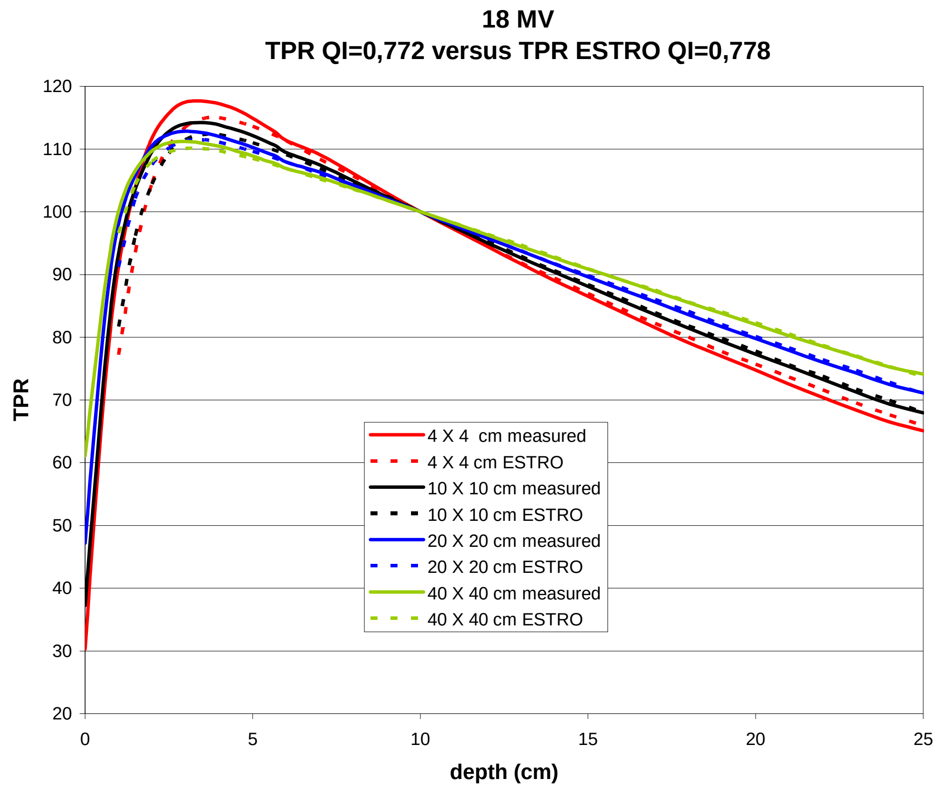

Figure 6. The TPR (measured and published by ESTRO), represented as a function of the depth, for 18 MV photon beam quality.

Using the measured data and applying linear approximation for the tissue phantom ratio calculations was done on MS Visual Basic. Further, using approximation formulas for the head scatter and volume scatter ratios, a monitor unit calculation program for regular and wedged fields has been created on the base of the MS Excel. In this program the input parameters were: the beam quality, field size, wedge, depth of the isocenter, and the dose per fraction. The verification of the MU calculation program was done by measurements with ionizing chamber, in a water phantom, at the depths representative for the real patient irradiation condition and by comparison with TPS calculated monitor units for clinical purposes. The difference between corresponding calculated monitor unit's dose for both 6 and 18 MV energies, and the measured or the calculated by TPS dose is within ±2% range.

IV. Conclusions:

From this study it could be concluded that, we reproduced with a good agreement the published data, except the TPR values for dept up to 5 cm.

The measured relative weight of upper and lower jaws - parameter *A* was dramatically different from the published data, but perfectly described the collimator exchange effect for our treatment machine.

No difference was found between the head scatter ratios, measured in a mini phantom and those measured with a proper brass buildup cap.

Our monitor unit calculation program was found to be reliable and it can be applied for check up of the patient's plans for irradiation with high energy photon beams and for some fast calculations. Because of the identity in the construction, design and characteristics of the Siemens accelerators, and the agreement with the published data for the same beam qualities, we hope that most of our experimental data and this program can be used after verification in other hospitals.

V. References

1. International Atomic Energy Agency (IAEA) 2001 Absorbed Dose Determination in External Beam Radiotherapy *(IAEA Technical Reports Series No. 398)* (Vienna: IAEA).
2. A. Dutreix, B. E. Bjarngard, A. Bridier, B. Mijnheer, J.E. Shaw and H. Svensson. Monitor Units Calculation for High Energy Photon Beams. ESTRO Booklet nr 3 Garant, Leuven-Apeldorn, 1997.
3. Mijnheer, B., A. Bridier, C. Garibaldi, K. Torzsok, J. Venselaar. Monitor Units Calculation for High Energy Photon Beams – Practical Examples. ESTRO Booklet nr 6, Brussels, 2001.