Introduction

IMRT treatments require a patient specific quality assurance (QA) before dose delivery. The QA include experimental verification in phantom of the total plan dose and dose distributions; these tests demand time and qualify staff to perform them. The use of independent dose calculation (IDC) could be useful in plan verification, as is done 3DCRT. Nevertheless, their application in IMRT requires implementation of an algorithm that considers the non uniformity of beam fluence.

The purpose of this work was to develop and validate an open source independent MU dose calculation software for S&S IMRT based in the algorithm proposed by Kung et.al (1).

Method and Materials

Treatment plans were done using a treatment planning system (TPS) Iplan v4.5 Brainlab TPS and S&S IMRT modality. A Primus linac (Siemens) with a 6MV photon beam equipped with Optifocus MLC was used. TPS dose calculation algorithms were Pencil Beam (PB) and Monte Carlo (MC). All IMRT treatment plans were exported to a solid water phantom where the dose was recalculated, then it was exported (RTP format) to the IDC. The IDC code was written under MATLAB 8.0 environment.

The algorithm proposed by Kung et.al. (1) uses a modified Clarkson integration (MCI), based on the concept that a beamlet at a distance r along the central axis (CAX) contribute equally to a beam dose dispersed along the CAX (Figure 1). The integrated dose is approximate by the sum of primary with a disk with radius r and scatter dose with annulus with radius f = r + Δr. The dose is as follows:

\[ D(d) = D(d, r)_{primary} + D(d, r + Δr)_{scatter} \]

\[ D(d) = S_p(r) \cdot TPR(r) \cdot MU(r) + \sum_i S_p(r + Δr) \cdot TPR(r + Δr) - S_p(r) \cdot TPR(r) \]

\[ D(d) = D(d) \cdot ISL \cdot OAR \cdot \%MLC_{transmission} \]

MU calculation algorithm

The modified Clarkson integral is applied as follows:

1. The fluence reconstruction is performed on a matrix where all segments of the field are added (Figure 2).
2. If the normalization point (PN(x, y)) is not the isocenter (P(x, y)), it is necessary to calculate the shift of the interest point from the CAX (OAD) using the coordinates of both points (Figure 3). The OAD depend on the gantry angle (Figure 4).
3. Calculation depth of each field is assumed to be the source isocenter distance minus the source surface distance (SSD).
4. The fluence is masked by disk and annuli, with the origin at coordinates PN seen by the field (Figure 5).
5. Dose is multiplied by the inverse square law (ISL), the off axis ratio (OAR) and MLC transmission.
6. The above steps are repeated for all fields, thereby calculating the total dose plan

Primary dose is calculated by disk with r equal to 1cm, secondary dose is calculated by annulus with Δr = 0.5cm thick.

The MLC transmission value was adjusted to improve the agreement between measured and calculated dose using the first 50 plans. The fluence is arranged an array of size 640x640 where 1 cm² correspond to 16x16 pixels.

Results

230 IMRT plans were analyzed. All plans had its own patient specific QA which included dose measurement in a solid water phantom with an ion chamber. The results of the maximum, minimum, average and standard deviation (σ) dose variation between TPS, using PB and MC algorithm, and IDC algorithm with dose measurement are summarized in Table 1. Table 2 shows that the dose variation between measurement and calculation using the IDC software is less than 5% (tolerance) for 99.1% of the plans and less than 3% for 91.3%. Plans with variation above the tolerance correspond to small volume (equivalent square field sizes < 5x5cm²) or normalization point close to high dose gradient region. Table 2 also shows the variation between dose measurement and TPS dose calculated using PB and MC algorithm is less than 5% for 97.8% and 100% respectively. Data have a normal distribution with respect to its average; histogram are shown in Figure 6, and differences graph are shown in Figure 7.

The user graphical interface of the IDC software is shown in Figure 8. The plan information can be read in RTP format. The coordinate of the isocenter and normalization point can be input manually.

Conclusion

The developed software is suitable for use in S&S IMRT dose calculation. This application is open and can be obtained upon request, future upgrade will be able to read DICOM.