Original Article

A Novel Algorithm in Radiation Dosimetry of Regular and Irregular Treatment Fields

Abstract

Background: The aim of this study was to design an algorithm for the calculation of monitor unit (MU) in a short time and high precision for different radiotherapy (RT) fields. **Materials and Methods:** The algorithm for calculating MU for the stated patients was designed in MATLAB software. To investigate the efficiency of this algorithm, 11 regular chest fields with the sizes of 7 cm × 7 cm up to 17 cm × 17 cm were considered, and the obtained MUs were compared with MUs of 13 patients which were calculated with a "hand calculation" which is used in some RT centers for the aforementioned fields. **Results:** The maximum percentage of calculation errors of regular fields at the depths of 4 and 10 cm were 1 and 0.8, respectively. The maximum and minimum percentage of calculation errors in irregular fields was 3 and 0.9, respectively. Furthermore, the maximum and minimum errors were 8.8 and 0.14, respectively. In addition, relative percentages of the MUs for irregular fields of chest and supraclavicular were 1.63 and 1.01, respectively. **Conclusion:** Calculation of MUs is suggested to be performed with the novel proposed algorithm, due to reduce the treatment time, and also provide high accuracy and precision compared to hand calculation.

Keywords: *Dose-calculation algorithm, monitor unit calculation, regular and irregular treatment fields*

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Introduction

In radiation therapy (RT), the delivery of the maximum radiation dose to the tumor and minimum dose to the surrounding healthy tissues is the most important goal of treatment planning. Monitor unit (MU) or treatment time is the calculations of treatment output ofLINACs for cancer treatment. The MU has been generated from treatment planning system (TPS) algorithms which are used in cancer centers. Therefore, the selection of a correct algorithm for calculation of MU plays a significant role in the delivery of the prescribed dose to the tumoral tissues.[1,2]

A number of factors affecting MU, which may lead to computation of this output complex and time-consuming and increased the errors in calculations.[2] To improve the accuracy of the quality of treatment calculations, it is essential to reduce the errors of MU calculations, and also dose distribution.[3,4] Many studies have been suggested that the required accuracy in delivered radiation dose between the central axis of the radiation beam and lateral sides of the tumors, could be 5%.[5,6] The two therapeutic techniques, including source-skin distance (SSD) and source-axis distance, are commonly used in clinical situation.

The aim of this study was to design an algorithm for calculation of MUs in a short time, and also with high accuracy for cancer treatment.

Materials and Methods

Hand calculation

Thirteen patients, who were suspected to have breast cancer according to their pathologic findings, were included in this study. The radiation treatment technique of them was two tangential photon beams, and also one direct photon field for the supraclavicular field. The treatment times (MUs) of them were calculated according to the following formula (Equitation 1):

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$$MU = \frac{TD}{\text{output factor} \times TMR(d, r_d) \times s_c(r_c) \times s_p(r_d) \times (\text{SAD factor}) \times \text{trayfactor} \times OAR(d, x) \times WF(d, r_d, x)} \quad (1)$$

Where the parameter r_c is the collimator opening size which is projected at the standard SSD. The tumor dose (TD) is prescribe TD. The above equitation is general and can be used for irregular and regular fields generated by blocks or collimators. For irregularly-shaped fields, the parameter r_d is the equivalent field size determined by Clarkson's technique or geometric approximation.[7-9]

Algorithm

In this study, an algorithm was developed for calculating the MUs of the patients, using MATLAB software (version 14, Athena, Greece). To investigate the efficiency of the designed algorithm, 11 regular fields with dimensions of 7 cm × 7 cm up to 17 cm × 17 cm were considered. The radiation doses were calculated using the algorithm. In this algorithm, the prescribed dose, accelerator output, and tumor depth were considered as inputs, and the MUs were obtained using the above equation. In the studied algorithm, the tray factor was considered 1 for regular fields. In this situation, the field sizes were considered as algorithm input, and the equal fields were obtained. As a result of equality of square fields of phantom and collimator, the MUs were obtained.

For MU calculation of irregular fields, the tray factor was not equal to 1. In this situation, square fields of phantom and collimator were not equal. Therefore, the Tissue- maximum ratio (TMR) and S_p and also MU were obtained for the square fields. The treatment time of the regular and irregular fields were obtained using TIC and TOC methods of MATLAB, respectively.

The validation of the algorithm was investigated through examining the stated 13 breast cancer patients by means of a linear accelerator (Elekta Compact, Sweden)[10-12] at Ayatollah Khansari Hospital (Arak, Iran). The values calculated by the algorithm were compared with those obtained by the clinical method.[13]

Results

Figures 1 and 2 compare dose calculations among the stated algorithm and clinical method for regular fields at the depth of 4 and 10 cm, respectively. According to Figure 1, the MUs for the 7 × 7, 8 × 8, 9 × 9, 10 × 10, 11 × 11, 12 × 12, 13 × 13, 14 × 14, 15 × 15, 16 × 16, and also 17 × 17 of the clinical method at the depth of 4 cm were, 225.3, 218, 214.8, 210, 207.5, 204, 200, 201, 196, 195.6, and 194, respectively. Whereas, the MUs for the mentioned algorithm were 224.5, 218.5, 214.5, 209.3, 206, 203, 201, 199, 196, 195, and 194, respectively [Figures 1 and 2].

Figure 2 illustrates the MUs for the 7 × 7, 8 × 8, 9 × 9, 10 × 10, 11 × 11, 12 × 12, 13 × 13, 14 × 14, 15 × 15, 16 × 16, and also 17 × 17 of the clinical method at the depth of 10 cm were 282, 216.5, 262.6, 254.5, 249, 244, 236.7, 236.5, 231.3, 228.4, and 227, respectively. Furthermore, the MUs for the stated algorithm were 280, 271, 262, 254, 248, 243, 239, 235, 231, 228, and 226, respectively [Figure 2].

Figure 3 gives a comparison between MUs of the proposed algorithm and clinical method for the treatment of the chest in irregular fields. The results showed that the MUs for the irregular fields were different among the algorithm and clinical method.

Figure 4 illustrates relative percentages of the MUs calculated by the algorithm and clinical method for the

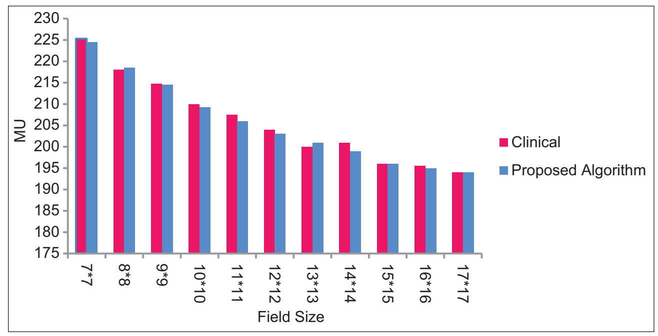

Figure 1: Comparison of the doses calculated by algorithm with those obtained from clinical method for the regular fields with a prescribed dose of 200 cGy at the depth of 4 cm

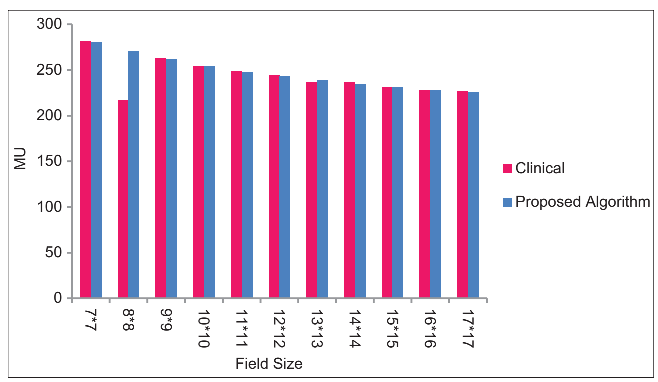

Figure 2: Comparison of the doses calculated by algorithm with those obtained from clinical method for the regular fields with a prescribed dose of 200 cGy at the depth of 10 cm

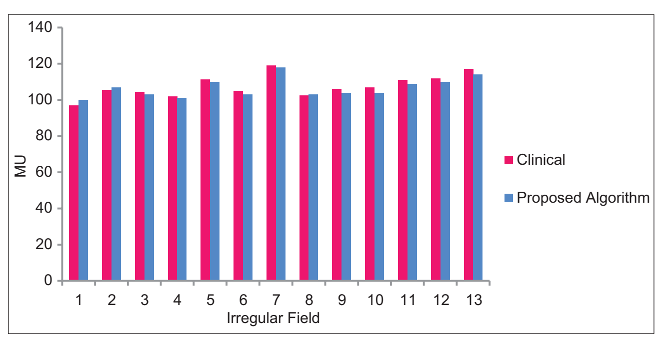

Figure 3: Comparison of the doses calculated by algorithm with those obtained from clinical method for the treatment of the chest

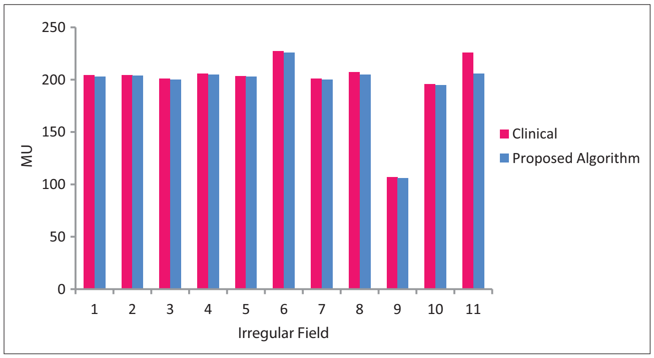

Figure 4: Relative percentages of the monitor units calculated by algorithm and clinical method for the treatment of the chest

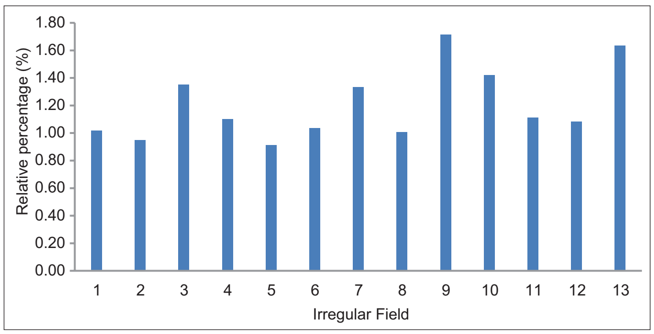

Figure 5: Comparison of the doses calculated by algorithm with those obtained from clinical method for the treatment of the supraclavicular nodes

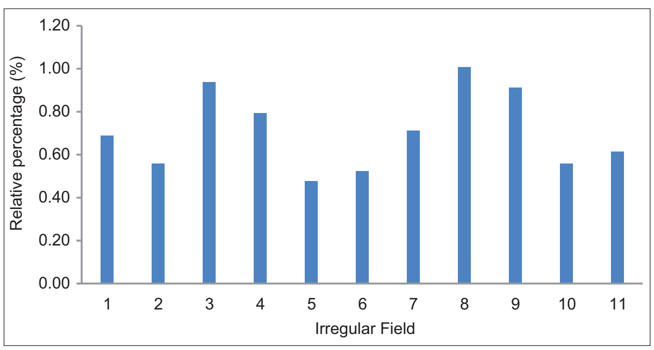

Figure 6: Comparison of the relative percentages of monitor units calculated by algorithm with those obtained from clinical method for the treatment of the supraclavicular nodes

RT of the chest. Figure 5 indicates a comparison among dose calculations of the algorithm with the calculations of clinical method for the irregular fields which are used to treat supraclavicular nodes.

Figure 6 compares relative percentages of the MUs calculated by the algorithm and clinical method for the RT of the supraclavicular nodes.

Discussion

One of the most important goals of treatment planning is to reduce the radiation dose to normal tissues in the treatment fields. Therefore, there are a number of algorithms have been used to calculation dose distribution in the tumors and their surrounding normal tissues in the clinical situation.[14,15] However, the algorithms may have errors in calculation of dose distribution in some in-homogeneities, irregular, and regular fields such as the lungs, ribs, and supraclavicular regions which are located at the treatment fields of breast cancer patients. Therefore, the study was performed to propose an algorithm for correct calculations of MUs in a short time, and also with high accuracy for all of the cancers.

Based on the results, the maximum percentage of calculation errors of regular fields at the depths of 4 and 10 cm were 1 and 0.8, respectively [Figures 1 and 2]. According to Figure 3, the maximum and minimum percentage of calculation errors in irregular fields were 3 and 0.9, respectively. Figure 5 shows that the maximum and minimum errors were 8.8 and 0.14, respectively. Relative percentages of the MUs for irregular fields of the chest and supraclavicular were 1.63 and 1.01, respectively [Figures 4 and 6]. The different values which were generated from the discussed algorithm compared to the hand calculation are mainly depended to consider the impact of important factors which are stated at the equitation 1. In addition, in the hand calculation, the MUs were estimated by extrapolating the factors.

Similar results have been reported in other studies. Golestani *et al*. have investigated the accuracy of the dose by means of a TPS using different computational methods, and the error rate has reported to be <3%.[16] Furthermore, Miften *et al*. have studied the dose distribution of tumor in the prostate, head, neck, and lungs using a TPS based on Clarkson and superposition algorithms. In the study, they found that the error rate was <4%.[17]

Sellakumar *et al*. have compared the MU which calculated by TPS with data generated from MU verification software. In their study, to ensure that the correct beam data was considered for MU calculations, the MU verification software was commissioned and tested for the data integrity. In addition, the accuracy of the calculations was tested by creating a series of test plans and comparing them with ion chamber measurements. In their study, it was found that there is a good agreement between the calculation of both of them.[18,19]

Our data showed that the calculation errors of the designed algorithm was <2%, compared to the conventional clinical approach. Moreover, the use of multiple factors in the calculation of MU and the delivery of a clinically prescribed dose to the tumor with high precision, which were performed for creating a similar condition for the two approaches, were indicative of the optimal accuracy and efficiency of the stated algorithm.

Based on the results, which are illustrated in Figures 2 and 6, the algorithm may provide suitable efficiency in the implementation of accurate calculations in a short time. According to Figures 4 and 6, the algorithm could be a good choice to reduce the treatment time compared to the hand calculation. Furthermore, this algorithm can be generalized to all RT centers for the treatment of different types of cancers with any accelerator model or energy.

Conclusion

There are many complex factors, which are effect on the treatment time and MU. The delivery of the prescribed clinical dose to the tumor with high precision is an issue of vital importance. Based on the results, the designed algorithm facilitated the implementation of accurate calculations within a short period. This algorithm can be used as double-check calculations of TPS.

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Conflicts of interest

There are no conflicts of interest.

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