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Development of spreadsheet for rapid assessment of therapeutic radiation dose delivery with electron and photon beams at various energies

Abstract

Accurate radiation therapy, dose calculation and quality control is the fundamental concern and objective for Oncologists and Physicists in Cancer Treatments. Global use of Radiation Therapy Machines like, ^{60}Co and LINAC (Old), demands an accurate and fast External Beam Radiation therapy (EBRT) machine dose evaluation, where treatment planning systems (TPS) are not available. Some of the cancer therapy centers do not have a medical physicist or a dosimetrist. For that, here we developed a spreadsheet named "Mithu" where Radiation Oncologists, physicists, and Radiotherapy technologists can easily calculate treatment time (TT) or Monitor Unit (MU) by Using an easy Microsoft Excel spreadsheets presented here. To create a treatment planning system for 2D or Emergency plan and Dosimetry need to calculate Cobalt-60 (^{60}Co) and *LINAC* Machine actual dose rate for source to surface distance (SSD) and Source to Axis Distance (SAD). Inside the spreadsheet Percentage depth dose (PDD), & Tissue Maximum Ratio (TMR), has been used from the British Journal of Radiology supplement 25 (BJR). Output factor, Wedge factor, and Tray factor have been used from machine commissioning data. The equivalent square field is another important and basic parameter for radiotherapy TT or MU calculation. Linac Machine dose rate is accurately calibrated by Quality Assurance procedures by Physicists which remains fixed, no decay. But ^{60}Co dose rate always decrease or changes as yearly decay constant is 0.131 (ln2/HL) and source decays 1.09% per month. To develop this spreadsheet some important Excel functions like HLOOKUP, VLOOKUP, EXACT, and logical function if-Else is mostly used for radiotherapy patients treatment plan dose calculation which has shortened the man-made hand calculation error by 99%. Almost 2000 patients' ^{60}Co Machine-based Radiotherapy treatment plan has been calculated using this "Mithu" Spreadsheets. Here we observed that ^{60}Co dose calculated is varied <1% where LINAC MU calculated is varying <1.5% which is an acceptable range in radiotherapy.

Keywords: EBRT, PDD, TMR, Dose, QA, MU, TT, treatment planning system, spreadsheet's, physicist, oncologist

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Introduction

The spreadsheet "Mithu" has been developed for a radiotherapy system where a treatment planning system was unavailable. Medical Physicist' time-saving in busy government and private radiotherapy centers in South Asia and the African region.[1] Another goal is that Medical physicist is not available in a government hospital (Some Asian & African country) so Radiation Oncologist & technologist make a treatment dose calculation manually.[2] So there have a probability to increase error in treatment dose. The manual dose calculation depends on some tables Like PDD, TMR, Output factor, etc. from the treatment machine. In BJR-25 table[3-5] field size & depth are in integer form except d-max depth (field size: 4x4, 6x6, 8x8, 10x10, 12x12, 15x15 cm,.....40x40 cm & Depth: 0.5, 1, 1.5, 2.4, 3, 4, 6, 8,10,12,15 cm..... 30 cm etc.). so if need to calculate a PDD for 7x7 cm field size & depth 4.3 cm its need to interpolate data from this table which is very time consuming procedure. So Spreadsheet "Mithu" will be the best solution for easy way treatment dose calculation. Another advantage of these Spreadsheets is that they can show the 25 days treatment dose schedule which is the same for *LINAC* all days schedule but ^{60}Co it is very important due to the disintegration of the radioactive source.[6-8] So 1st fraction dose to the 25th fraction dose will not be the same for ^{60}Co. Every day its changes a little bit. So physicists don't need to correct the treatment dose every month for ^{60}Co EBRT if they use it. Before apply the dose to the cancer patient's one physicist needs to know how much dose exit from the machine at specific distance called source to surface distance. Most of the linear accelerator has SSD 100cm and Most of the ^{60}Co machine has SSD 80 cm but SSD 100 ^{60}Co machine now a day available in market.[9,10] After strike (Y-ray or X-ray) a surface dose is accumulated at a point in ward from the surface is called D-Max. So it is important to know how much dose is accumulated per minute for ^{60}Co source and per MU for *LINAC* in dose maximum (D-max) at fixed reference condition (field size 10x10 cm, SSD 80 or 100 cm, Chamber position 5 cm or 10 cm depth form water surface depend on Machine energy).[11,12] TRS-398 & TG-51 have the details protocol for absolute dose measurement. Spreadsheet **"**Mithu" have this good and easy solution followed by TRS-398.Also In modern radiotherapy system after installation a ^{60}Co or Linac machine Medical physicist start beam data acquisitions work using 3D water phantom, 2D Water Phantom, Farmer type ionization chamber (volume =>0.6cc), diode or small volume ionization chamber for small field dosimetry. After completed acceptance test its take few days for machine commissioning. So our spreadsheet **"Mithu"** will be the good tools /for verifying the TPS System. As per BJR Suplimentary-25 data table for *LINAC* Machine we know that, 6MV photon beam have 67% dose and ^{60}Co have 56% dose at 10 cm depth for 10x10cm collimator jaw setting. So if we deliver a dose 200cGy at 10 cm depth than 298.5 cGy dose (Beam is calibrated 1 MU = 1cGy) need to deliver. So in TPS we can delivery same dose in water phantom at same depth and observed that, our TPS calculated dose near about 298.5 cGy. If the calculated dose

vary more that 2% from our Spreadsheet "Mithu" than again need to check the commissioning data. Most of the duel energy Linac have Photon (X-ray) & Electron (e-) therapy treatment option.[13] So electron therapy we need to know the cutout factor, energy verses collimator jaw setting, output factor and percentage depth dose which will be acquired at the commissioning time.[14] Spreadsheet "Mithu" have this option to calculate dose for electron therapy. Patient's database is the very important part in radiotherapy center. Patients Address, contact number, diagnosis and treatment dose assign doctors & physicist name need to record in database. So that easily physicist can say home much patients be treated per year or month. Can be analysis, which type of organ (site) is treated more and demographic basis which type of patients is more. Admin panel is the heart of this Spreadsheet "Mithu" After commissioning every date must be put inside the admin panel for Cobalt-60, *LINAC* and Electron dose calculation. This Spreadsheet "Mithu" is uploaded in "https://lnkd.in/gcrr-G-J*"& "*https://lnkd.in/gkF7csri" site which can be downloaded for use in any site shows in Figure 1.

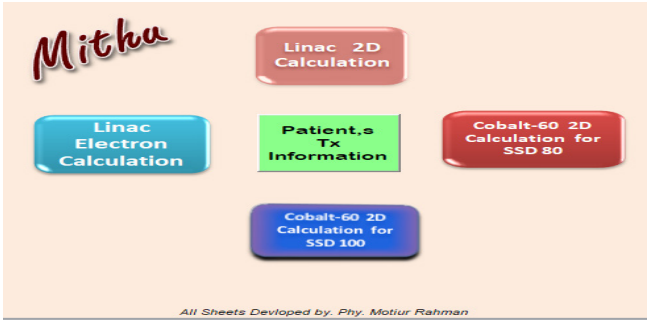

Figure 1 Main panel of Spreadsheet "Mithu".

Material and methods

I.A material: In the present study & development, essential tools are Microsoft Excel & Visual basic measurement from machine specific data absolute dosimetry, output factor, wedge factor, tray factor etc. PDD & TMR table used from BJR Suppl. 25(1996) both for ^{60}Co & Linac (6 & 10 MV) beam. Some important function HLOOKUP (), VLOOKUP (), Exact () and logical function **IF, Or, AND** is mostly used. HLOOKUP (), VLOOKUP () we use here to extract data from the table. HLOOKUP searches for the value in a table row & VLOOKUP search for the value in a table column. HLOOKUP (), VLOOKUP () will get exactly the same result, but the table is arranged differently. EXACT function compare between two strings. IF function allows to make a logical comparison between a value like =IF (Something is True, then do something, otherwise do something else). AND, OR and NOT is an individual functions but we use it here as a combine an IF statement Example =IF (OR (Something is True, Something else is True), Value if True, Value if False). Microsoft Visual Basic is the tools which are built in with Microsoft office. Just need to active the developer option from file options menu inside the Microsoft excel. TRS-398 data and formula is also use for Absolute dosimetry. The objective of this work may, therefore, be taken as a reference for any user or, can create spreadsheets their own style for the machine treatment Time/MU verification of quality performance of the machine, while using it at any Cancer Treatment Center (CTC). Detailed information on materials and methods are compiled here.

I.B methods

Admin Panel: The admin panel (or the Administration Panel) is the primary tool for any kind of radiotherapy software. Though **"Mithu"** is an excel spreadsheet and we were developed a separate sheet inside the **"Mithu"** can say admin panel for input the basic machine-specific data before using these spreadsheets in their cancer therapy center. This admin sheet will be the interlink with others user sheets. So it will be very easy to use these spreadsheets if only once a time input the basic data Like Output factor, Wedge factor, Machine calibration value (1 MU = ?) or ^{60}Co dose rate input . Evoke that, computer date and time is a very important and sensitive issue for the ^{60}Co time calculation spreadsheet. Because radioactive source activity decay with the day (Figure 2).

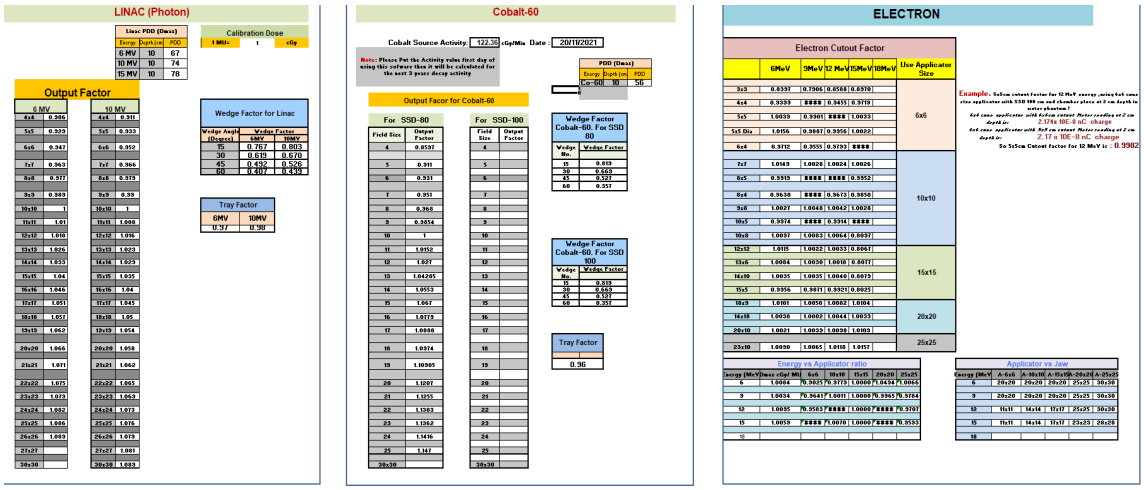

Figure 2 Admin panel arrangement for the "Mithu" software.

Radiotherapy treatment plan: In house radiotherapy treatment planning system "Mithu" has been developed for Linac 6MV & 10MV photon energy emergency radiotherapy or 2D treatment plan for MU calculation, ^{60}Co radiation therapy 2D treatment plan for treatment time calculation also can be easily cross check commercial treatment planning systems. Inside the treatment planning excel Spreadsheets "List" function were used from Data Menu for selectable data. Example: In our Linac Spreadsheets we can change energy and technique just press on energy cell and select energy, same for treatment technique, Tx Area, Machine, Physicist, and oncologist cells.

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It's has an advantage is that:

a) Its can use both SSD & SAD method treatment calculation. Just change the Treatment Technique option.

b) Its can make treatment plan schedule as per treatment fraction.

c) No need manual data sheet table. It's have the intelligence to find out PDD, TMR, Equivalent Square Field (ESF)[3]

d) No need decay correction in patient's treatment card for ^{60}Co EBRT patients.

e) All kind of correction factor can be associated with TT or MU (Figure 3,4).

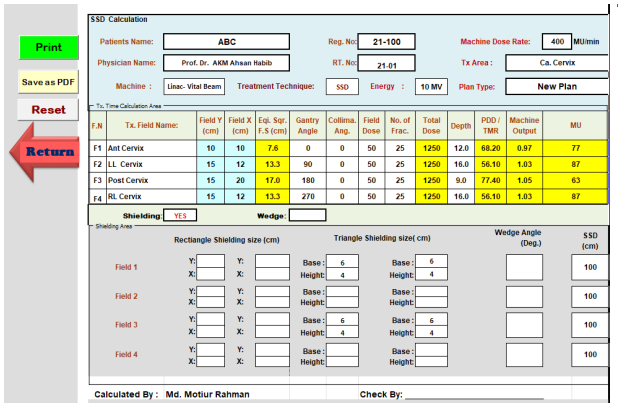

Figure 3 Linac 2D treatment planning Spreadsheets which can be used for 6 & 10 MV photon dose calculation both for SSD &SAD method.

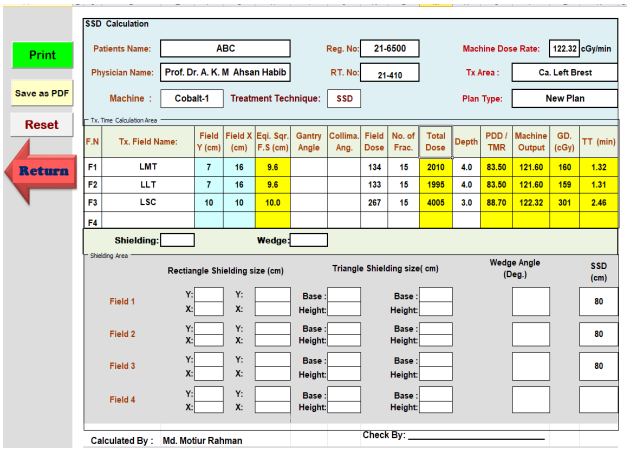

Figure 4 ^{60}Co treatment planning Spreadsheets. Can perform treatment time or dose calculation.

Basic Equation for Manual dose calculation is used in a center is:

For Cobalt-60 (^{60}Co)

$$TT = \frac{\text{Prescribed dose}}{\text{Dose rate} \times \%DD \text{ or } TMR \times \text{Output factor}} \quad (1)$$

For Linac

$$MU = \frac{\text{Prescribed dose}}{\frac{cGy}{MU} \times \%DD \text{ or } TMR \times \text{Output factor}} \quad (2)$$

Normally the dose rate for the Linear accelerator is 1cGy/MU for 10x10 cm field size defined at the iso-center, Percentage depth dose is depend on the equivalent square field (ESF) and the prescribed depth.

Output factor is Total scattering factor which is measured at machine commissioning time. Some others factor we can also use like Wedge and Tray factor depends on organ shielding and beam hinge angle. In this developed software we use this equation (1) and (2) for treatment Time and Monitor Unit (MU) calculation.For electron therapy we use a different size of Applicator and cone cutout factor for different energy. Most of the Linac in cancer center have 4 to 6 electron energy step. Here we develop this spreadsheet using VARIAN machine which have an energy step 6 , 9, 12, 15, 18 & 22 MeV among of them first four energy steps (6,9,12,15 MeV) has been used most of the clinical treatment purpose rest of the two energy steps (18, 22 MeV) seldom use in clinical treatment purpose. Varian machine has an applicator cone size 6x4, 6x6, 10x10, 15x15, 20x20, 25x25cm. Collimator jaw setting depends on cone size vs machine physics setting. Here we use VARIAN common setting for iX machine data setup in Delta Hospital Ltd. Mirpur-1, Dhaka. Different field size cutout can be made in house for clinical use and output factor can be determined as per energy. All of the measured date Applicator size, Cutout factor we can put inside the admin sheet in electron spaces. HLOOKUP () is the main excel function in this spreadsheet. Its can horizontally search the data from the table as per selection electron energy, cone cutout (Table 1).

Table 1 Electron Applicator vs Collimator Jaw setting. From the spreadsheet admin panel anyone can change as per their machine setting

	6x6	10x10	15x15	20x20	25x25
6	20x20	20x20	20x20	25x25	30x30
9	20x20	20x20	20x20	25x25	30x30
12	12x12	14x14	17x17	25x25	30x30
15	11x11	14x14	17x17	23x23	28x28
18					
22					

Results & discussion

Figure 5 & 6 shows the applications of in house Spreadsheets (name "Mithu") from the year 2012 for radiotherapy patients treatment plan dose calculation which has shortened the man-made hand calculation error by 99%. Almost 2000 patients' ^{60}Co Machine based Radiotherapy treatment plan has been calculated using this **"Mithu"** software at Rajshahi Medical College and Hospital, Rajshahi, National Institute of Cancer research Hospital, Dhaka, Dhaka Medical College and Hospital, Dhaka and Delta Hospital Ltd., Dhaka for a precise treatment, Hospital Physicist Association,[1] Central Axis Depth dose data for radiotherapy (BJR Suppliment-11) published an equivalent Square of rectangular fields table.

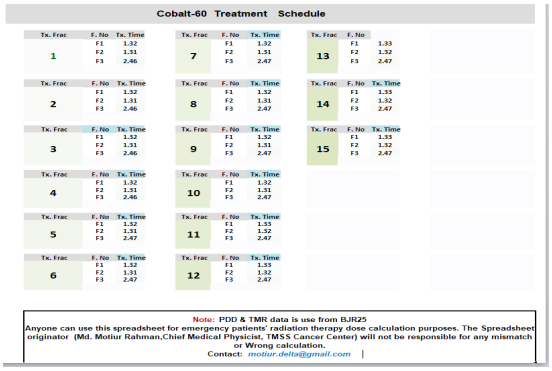

Figure 5 ^{60}Co treatment time schedule depends on the fraction. As per plan & field it can able to visualize the treatment information. Be used for 6 & 10 MV photon dose.

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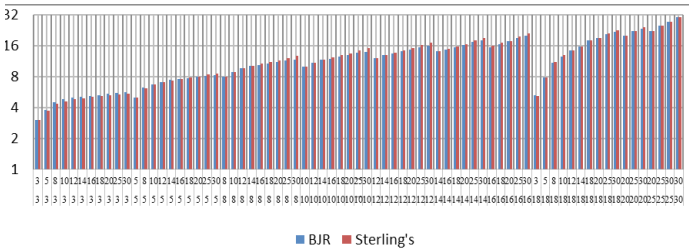

Figure 6 Shows Graphical representation between Hospital Physicist Association and sterling equation of deviation.

Table 2 and 3 show that the deviation of calculated MU is less than ±1.5% for 6 and 10 MV photon beam between the Commercial TPS system and "Mithu" spreadsheet. Figure 7 shows the Sterling et al.,[2] equation and Hospital Physicist Association table[3] comparative deviation between equivalent square field. The sterling equation is almost matched with Hospital Physicist Association table for small field size <10 cm but it can vary for >10cm. Example 12cm X 24 cm rectangular field size as per sterling equation its equivalent square field size is 16 cm but Hospital Physicist Association table says 15.4 cm so deviation is 6 mm. or 3.9%. Below *Graph1:* shows Graphical representation between Hospital Physicist Association and sterling equation deviation. So its deviations have little bit impact on TT/MU calculation due to change of PDD & TMR value but are negligible. Using both BJR Table and Sterling's Equation all the equivalent Square field size output factors were not very too much.

Figure 8 shows the experimental result we got the output deviation between these two methods is maximum ±0.45% for ^{60}Co ±0.4% for 6MV & ±0.23% for 10MV which is not much impact on clinical dose calculation for radiotherapy treatment. Grah2 & 3 Shows the output variation for X & Y jaw setting. For PDD and TMR we got some deviation between BJR and Machine commissioning data which is not more than 2%. As per ICRU50 +7% and -5% is the acceptable dose for the prescribed dose.

Table 2 6MV, 10x10 cm field size has been calculated at various depths using Commercial TPS system and "Mithu" spreadsheet and their deviation

Treatment Depth (cm)	Eclipse Planning System Data		"Mithu" Planning System Data & Result		Deviation ±Δ%
	% DD	Calculated MU	% DD	Calculated MU	
5	86.55	231	86.9	230	0.41
10	67	299	67.5	296	0.85
15	51.2	391	51.7	387	0.94
20	38.9	514	39.3	509	1.01

Table 3 10MV, 10x10 cm field size has been calculated at various depths using Commercial TPS system and "Mithu" spreadsheet and their deviation

Treatment Depth (cm)	Eclipse Planning System Data		"Mithu" Planning System Data & Result		Deviation ±Δ%
	% DD	Calculated MU	% DD	Calculated MU	
5	91.6	218	91.4	219	-0.30
10	73.5	272	73	274	-0.69
15	58.2	344	57.8	346	-0.68
20	46	435	45.6	439	-0.96

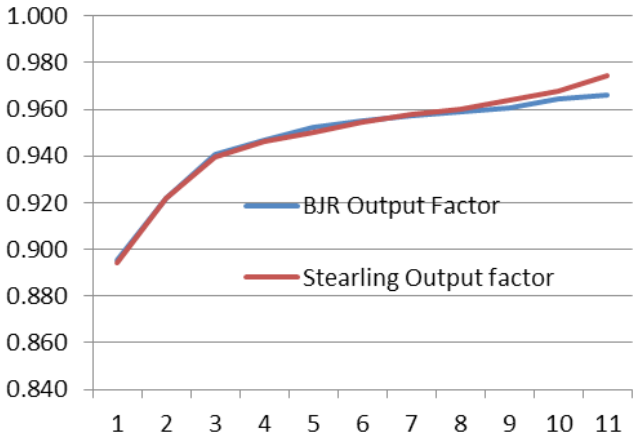

Figure 7 Output Variation with fixed Y and Variable X Jaw for (3 X x_j) 6MV Photon energy.

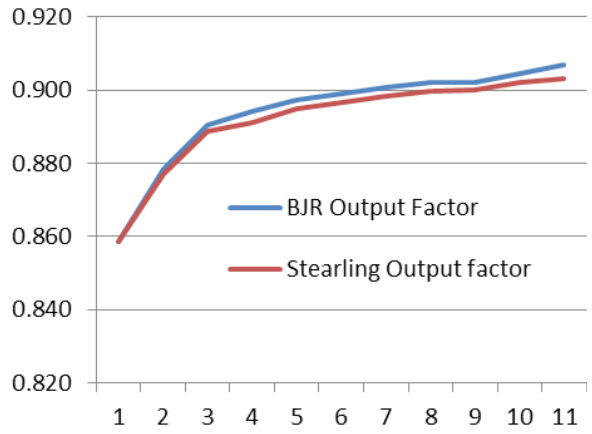

Figure 8 Output Variation with fixed Y and Variable X Jaw for (5 X x_j) 6MV Photon energy.

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Conclusion

Modern radiation therapy quality assurance (QA) devices and treatment planning systems are available in the market. But in some government hospitals or Radiation therapy centers in South Asia and Some African countries use ^{60}Co and LINAC Machine where TPS is not available and Medical Physicist is not appointed. The developed spreadsheet can be used for the purpose of quality and accurate Dose delivery in radiation therapy in addition to QA purposes. It's also the cost-effective solution for the center where a commercial planning system is not available. Assurance of quality radiation therapy is presented here. It will be a good solution where, physicists and dosimetrist are not available. So that, error-free treatment may be delivered. Some busy centers will be helpful for saving the physicist's time and shortening patients waiting time for radiotherapy card preparation and calculation.

Compliance with ethical standards

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Conflicts of interest

Authors declare that there is no conflict of interest.

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