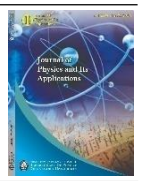
Journal of Physics and Its Applications

Journal homepage : https://ejournal2.undip.ac.id/index.php/jpa/index



Verification of Point Dose on MU Calculator for Bleeding Cases

Zamakhsari Alhamid[1*], Arief Dian Ramadan[1], Wahyu Edy Wibowo[2], and Choirul Anam[3]

[1]*Departement of Radiation Oncology, Mitra Plumbon Hospital, Cirebon, Indonesia*
[2]*Departement of Radiation Oncology, Cipto Mangunkusumo Hospital, Jakarta, Indonesia*
[3]*Departement of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia*

[*]*Corresponding author: zamakhsari.2018@fisika.fsm.undip.ac.id*

A R T I C L E I N F O

Article history:
Received: 17 October 2024
Accepted: 13 April 2025
Available online: 31 May 2025

Keywords:
Verification
Point dose
MU Calculator
Bleeding

A B S T R A C T

Bleeding is a frequent issue among cancer patients, affecting about 6% to 10% of those with advanced-stage cancer. External radiation therapy is a highly effective method for reducing or even stopping bleeding, with success rates ranging from 45% to 100%. In bleeding cases, radiation therapy must be delivered quickly and precisely. To expedite the process, some standard steps in radiation therapy, such as the CT simulation and planning via the treatment planning system (TPS), are often skipped. Consequently, accurate Monitor Unit (MU) calculations are essential to ensure that the dose received by the patient does not deviate by more than 5%, as recommended by the ICRU. Using guidelines from AAPM TG 71, MU calculations were formulated and compiled into a Microsoft Excel worksheet called the MU Calculator. Several key parameters, including dose prescription, output factor (OF), and tissue maximum ratio (TMR), were input into the MU Calculator and verified through point dose verification on a slab phantom using the SAD technique. The verification was conducted using 10 MV energy across various field sizes (10 x 10, 12 x 12, 14 x 14, 16 x 16, 18 x 18, and 20 x 20) cm^2 at depths of 6, 8, and 10 cm, utilizing a PTW Farmer detector with dose prescriptions of 200, 300, and 400 cGy. The field size, depth, and dose prescription were selected to align with common requirements for bleeding cases. By applying the dose calculation formula recommended by TRS 398, the deviation between the prescribed and measured doses was found to be less than 2.5%. These deviations were attributed to factors such as measurement setup, temperature and pressure conditions, polarity effects, and detector recombination effects. The MU Calculator has been validated, demonstrating compliance with ICRU recommendations, and is thus suitable for use in bleeding cases that demand swift and precise external radiation therapy.

1. Introduction

Bleeding is a frequent complication in cancer patients, affecting approximately 6% to 10% of those with advanced-stage disease [1]. Bleeding tumors can present in various ways, including vomiting blood (hematemesis), coughing up blood (hemoptysis), blood in the urine (hematuria), rectal or vaginal bleeding, as well as bruising, petechiae, or other forms of bleeding under the skin. The bleeding may occur gradually in large amounts or persistently in smaller amounts, significantly impacting the patient's quality of life by causing anxiety, distress, and potentially leading to death. This bleeding can be caused by damage and invasion of local blood vessels or by systemic issues such as disseminated intravascular coagulation (DIC) or platelet dysfunction or deficiency. To choose the appropriate intervention, it's important to consider the underlying cause of the bleeding, the patient's potential for recovery, and the balance between the burden of treatment and the potential benefits. These decisions should take into account the patient's overall health, life expectancy, and treatment objectives. If the goal is curative, general resuscitation measures like blood transfusions and specific interventions to control the bleeding are necessary. However, if the treatment focus is palliative, the emphasis is on comfort rather than aggressive resuscitation. Various treatment options can help manage and stop bleeding, including discontinuing anticoagulants, using pressure dressings, surgery, embolization, or radiotherapy. The choice of treatment depends on the bleeding's anatomical location and its specific characteristics.

Radiotherapy is an effective method for reducing and stopping bleeding, with success rates ranging from 45% to 100% [2]. Ideally, patients should receive treatment according to a set schedule, typically within 3 to 7 days from their initial consultation with a radiation oncologist to the start of treatment. This timeframe allows for a thorough assessment of the treatment indications, diagnostic imaging results, and treatment planning. The general workflow for radiation therapy includes

determining the clinical indications, performing CT imaging for planning and treatment, delineating the target volume and organs at risk (OAR), prescribing the dose, planning the treatment using a treatment planning system (TPS), and verifying patient positioning and the delivery of radiation [3].

Bleeding cases are classified as oncology emergencies, defined as "conditions arising from a reversible threat to organ function that require radiation treatment within hours of diagnosis" [3]. Prompt action is necessary to shorten the time interval, ensuring dose accuracy. A streamlined workflow involves eliminating the CT imaging of the target and modifying the treatment planning process. By switching from the traditional TPS to an Excel-based "MU Calculator" (see Figure 1), the goal is to quickly convert the prescribed dose to Monitor Units (MU) without manual calculations.

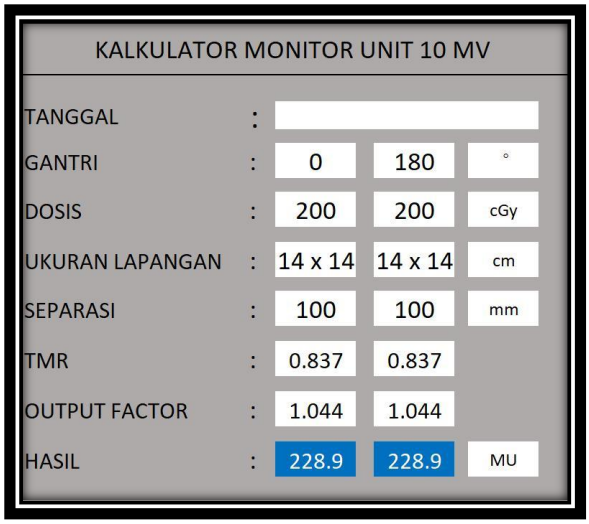


Fig. 1: Display of the Excel-based MU Calculator

Accuracy in radiation therapy is crucial, as radiation has the dual effect of killing cancer cells while also damaging surrounding healthy tissue. To ensure precision in planning, deviations should be less than 5% (according to ICRU recommendations) [7] or 3.5% as suggested by B.J. Minjnheer [8]. Point dose verification can be used to confirm the accuracy of the dose delivered to the patient, including the accuracy of the MU Calculator that has been established.

2. Method

Using the output factor (OF) and tissue maximum ratio (TMR) data obtained during commissioning of the Elekta Synergy Platform Linear Accelerator, an Excel-based MU Calculator was developed to compute the conversion of prescribed doses into Monitor Units (MU). The equations used in the calculator are based on the recommendations from the American Association of Physicists in Medicine (AAPM) Task Group (TG) 71 [6].

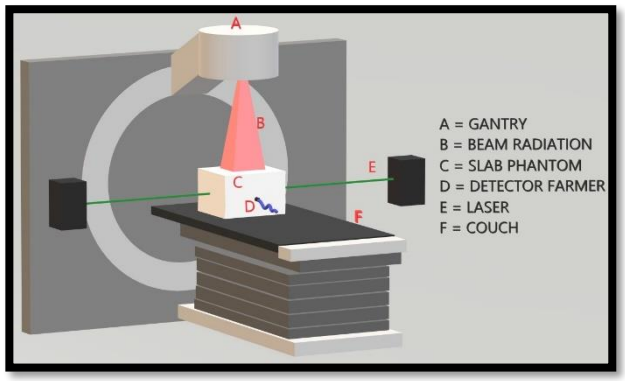


Fig. 2: Point Dose Verification Setup

$$\text{MU} = \frac{\text{prescription dose}}{\dot{D} \text{ x OF x TMR}} \quad (1)$$

Here, MU represents the monitor unit, $\dot{D}$ is the dose rate to MU ratio at reference conditions (1 cGy/1 MU), OF is the output factor, and TMR is the tissue maximum ratio.

Point dose verification was performed on the MU Calculator using 10 MV energy with a PTW Farmer detector, UNIDOSE Romeo electrometer, and a Slab Phantom, employing the Source – Axis Distance (SAD) technique. The setup is shown in Figure 2, and the measurement variations are as follows: 1) Dose Prescriptions were 200, 300, and 400 cGy; 2) Depth was 6 cm, 8 cm, and 10 cm; 3) Field size was 10 x 10 cm^2, 12 x 12 cm^2, 14 x 14 cm^2, 16 x 16 cm^2, 18 x 18 cm^2, dan 20 x 20 cm^2.

According to the recommendations from the International Atomic Energy Agency (IAEA) in Technical Report Series (TRS) 398, before calculating the absolute dose, the measured charge must be converted into a corrected charge. This conversion involves applying four recommended correction factors: polarity correction factor, electrometer correction factor, recombination correction factor, and temperature and pressure correction factor, as indicated in Equation 2 [9].

$$M_c = M_m \text{ x } K_{pol} \text{ x } K_{elec} \text{ x } K_s \text{ x } K_{TP} \quad (2)$$

M_c = Corrected charge (nC)
M_m = Measured charge (nC)
K_{pol} = Polarity correction factor
K_{elec} =Electrometer correction factor
K_s = Recombination correction factor
K_{TP} = Temperature and pressure correction factor

Once the corrected charge is obtained, the next step is to convert this corrected charge into an absolute dose using two correction factors: the chamber correction factor and the beam quality correction factor, as outlined in Equation 3 [9].

$$D_{wQ} = M_c \text{ x } N_{DwQ} \text{ x } K_{qq_0} \quad (3)$$

D_{wQ} = Absolute dose (cGy)
N_{DwQ} = Chamber correction factor $\left(\frac{cGy}{nC}\right)$
K_{qq_0} = Beam quality correction factor

The absolute dose obtained from the measurements is then compared to the prescribed dose using the dose difference percentage (deviation) formula, as shown in Equation 4 [5].

$$\%\ DD = \frac{D_m - D_p}{D_m} \times 100\% \quad (4)$$

% DD = Dose different (%)
D_m = Measured dose (cGy)
D_p = Prescription dose (cGy)

The complete scheme of the process for creating and verifying the point dose with the MU Calculator is illustrated in Figure 3.

3. Result and Discussion

The MU Calculator has been verified using point dose verification protocols. The results show that at a depth of 6 cm, for a prescribed dose of 200 cGy, the measured dose range is (197.5 cGy – 204.5 cGy), with the maximum deviation being 2.23%.

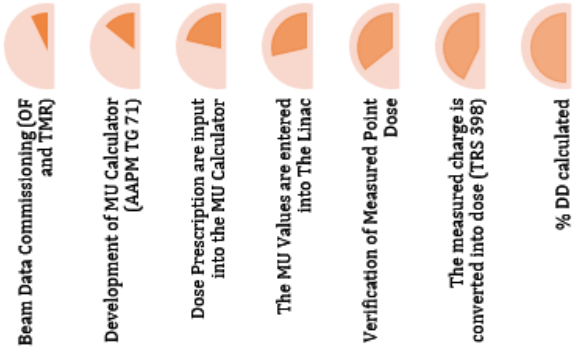


Fig. 3: Diagram of the process (start from left and finish on right) for developing and verifying point doses using the MU Calculator

For a prescribed dose of 300 cGy, the measured dose range is (296.5 cGy – 306.8 cGy), with the maximum deviation at 2.26%. For a prescribed dose of 400 cGy, the measured dose range is (395.5 cGy – 409.1 cGy), with the maximum deviation of 2.28%. These results are detailed in Table 1.

Table 1: Comparison of prescribed and measured doses at a depth of 6 cm

Field Square (cm²)	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD
	Pres.	Meas.		Pres.	Meas.		Pres.	Meas.	
10 x 10	200	204.5	2.23	300	306.8	2.26	400	409.1	2.28
12 x 12	200	202.7	1.35	300	304	1.34	400	405.5	1.39
14 x 14	200	202.7	1.29	300	302.7	0.89	400	403.8	0.94
16 x 16	200	200.7	0.33	300	300.9	0.31	400	401.5	0.38
18 x 18	200	199.6	0.19	300	299.5	0.17	400	399.6	0.10
20 x 20	200	197.5	1.26	300	296.5	1.16	400	395.5	1.13

At a depth of 8 cm, the measured dose range for a prescribed dose of 200 cGy is (199.3 cGy – 204.4 cGy), with the maximum deviation being 2.18%. For a prescribed dose of 300 cGy, the measured dose range is (299 cGy – 306.8 cGy), with the maximum deviation at 2.28%. For a prescribed dose of 400 cGy, the measured dose range is (398.7 cGy – 409.1 cGy), with the maximum deviation of 2.34%. These details are shown in Table 2.

Table 2: Comparison of prescribed and measured doses at a depth of 8 cm

Field Square (cm²)	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD
	Pres.	Meas.		Pres.	Meas.		Pres.	Meas.	
10 x 10	200	204.4	2.18	300	306.8	2.28	400	409.3	2.34
12 x 12	200	203.3	1.63	300	305.1	1.70	400	407.4	1.84
14 x 14	200	202.5	1.27	300	303.8	1.27	400	405.2	1.31
16 x 16	200	201.7	0.83	300	302.6	0.87	400	403.6	0.89
18 x 18	200	201	0.51	300	302	0.66	400	402.3	0.58
20 x 20	200	199.3	0.35	300	299	0.35	400	398.7	0.32

At a depth of 10 cm, the measured dose range for a prescribed dose of 200 cGy is (199.4 cGy – 204.4 cGy), with the maximum deviation being 2.21%. For a prescribed dose of 300 cGy, the measured dose range is (298.6 cGy – 306.8 cGy), with the maximum deviation at 2.26%. For a prescribed dose of 400 cGy, the measured dose range is (398.1 cGy – 409.0 cGy), with the maximum deviation of 2.25%. These results are detailed in Table 3.

Table 3: Comparison of prescribed and measured doses at a depth of 10 cm

Field Square (cm²)	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD	Absolute Dose (cGy)		(%) DD
	Pres.	Meas.		Pres.	Meas.		Pres.	Meas.	
10 x 10	200	204.4	2.21	300	306.8	2.26	400	409	2.25
12 x 12	200	203.2	1.58	300	304.7	1.58	400	406.7	1.69
14 x 14	200	202	1.01	300	303.2	1.06	400	405.3	1.33
16 x 16	200	201.4	0.7	300	301.7	0.57	400	402.6	0.64
18 x 18	200	201.2	0.62	300	301.1	0.37	400	401.5	0.38
20 x 20	200	199.4	0.29	300	298.6	0.47	400	398.1	0.48

The deviations are influenced by measurement setup and several factors affecting the ion chamber detector measurements, such as air density conditions, polarity effects, and recombination effects. Measurement setup is a significant factor affecting results and can be controlled by the user, as it is subjective (based on detector and phantom usage and positioning). This issue is discussed in AAPM TG 142 and is included as one of the causes for action level category 1 (inspection action) [10]. To minimize these issues, we conducted repeatability measurements to ensure that our measurements were precise, by examining the standard deviation derived from the measurements. A smaller standard deviation indicates better precision of the measurements.

The charge recorded by the ion chamber detector is influenced by air density, because most ion chamber detectors interact with the surrounding air. Air density varies with temperature, pressure, and humidity [9]. In this case, the temperature is measured at 21.3°C compared to a reference temperature of 20°C, the pressure is measured at 101.25 kPa compared to a reference pressure of 101.325 kPa, and the humidity is measured at 60% compared to a reference range of 45–55%. Thus, a

temperature and pressure correction factor (K_{TP}) of 1.0051 is needed.

The polarity effect is a factor influencing measurement values in ion chamber detectors. This effect arises from differences in charge conditions when applying opposing voltages (+) and (−). A polarity effect is deemed acceptable if its value is 1 with a tolerance of 0.3% [12] or within 0% deviation, with an allowable deviation between measurements of less than 3% [11]. This indicates that the ion chamber detector is suitable for use. However, the polarity effect can vary based on beam quality and other factors like cable position, making it essential to correct for this effect each time absolute dose measurements are performed.

Charge loss in ion chamber detectors results from recombination effects, where positive ions capture free electrons and combine with them or with negative ions to form new neutral atoms [11]. This effect impacts the measurement values. To ensure that the loss of charge is minimal, a recombination correction factor is necessary. The measured value of this correction factor (K_s) is 0.9847.

A further correction needed for the ion chamber detector is the electrometer correction, which is relevant if the electrometer is calibrated separately (as is common in the United States). In contrast, in other countries like Canada, the electrometer and ion chamber are usually calibrated together as a single unit. When the electrometer is calibrated separately from the ion chamber, the electrometer correction factor, K_{elec} adjusts the electrometer readings to reflect the true coulomb values. This correction factor is provided by an Accredited Dosimetry Calibration Laboratory and corresponds to the range used on the electrometer. When the electrometer and ion chamber are calibrated together, K_{elec} is taken as 1 [12].

4. Conclusion

Overall, the dose verification deviations at each depth showed values of less than 2.5%. These results meet the criteria based on ICRU recommendations with a tolerance of < 5% and the B. J. Mijnheer journal with a tolerance of < 2.5%. Therefore, the MU Calculator is suitable for use in urgent patient cases such as bleeding or other situations requiring rapid and accurate intervention which is better known as Cito.

Acknowledgments

This research was supported by the Mitra Plumbon Hospital Cirebon.

Reference

[1]. J. Pereira and T. Phan, "Management of Bleeding in Patients with Advanced Cancer" The Oncologist, 9, 561-570, (2004).

[2]. J. Strijbos, Linder, Y. M. V. D., and Vos-Westerman, H., "Patterns of practice in palliative radiotherapy for bleeding tumours in the Netherlands; a survey study among radiation oncologists" Clinical and Translational Radiation Oncology, 15, 70-75, (2019).

[3]. L. Nierer, F. Walter, M. Niyazi, R. Shpani, G. Landry, S. Marschner, R. von Bestenbostel, D. Dinkel, G. Essenbach, M. Reiner, C. Belka, and S. Corradini, "Radiotherapy in oncological emergencies fast-track treatment planning" Radiation Oncology, 15, 215, (2020).

[4]. A. Kumar, G. Mukherjee, G. Yadav, V. Pandey, and K. Bhattacharya, "Optimized point dose measurement: An effective tool for QA in intensity-modulated radiotherapy" Journal of Medical Physics, 32, 4, (2007).

[5]. L. Dong, J. Antolak, M. Salehpour, K. Forster, L. O'Neill, R. Kendall, and I. Rosen, "Patient-specific point dose measurement for IMRT Monitor Unit Verification" International Journal of Radiation Oncology Biology Physics, 56, 3, (2003).

[6]. J. P. Gibbons, J. A. Antolak, D. S. Followill, M. S. Huq, E. E. Klein, K. L. Lam, J. R. Palta, D. M. Roback, M. Reid, and F. M. Khan, "Monitor unit calculations for external photon and electron beams: Report of the AAPM Therapy Physics Committee Task Group No. 71" Medical Physics, 41, 3, (2014).

[7]. ICRU, "International Commission on Radiation Units and Measurements. Prescribing, Recording, and Reporting Photon Beam Therapy, Supplement to ICRU Report No. 50. ICRU Report 62" Bethesda, MD: ICRU, (1999).

[8]. B. J. Mijnheer, J. J. Battermann, and A. Wambersie, "What degree of accuracy is required and can be achieved in photon and neutron therapy" Radiotherapy and Oncology, 8, 237-252, (1987).

[9]. IAEA, "International Atomic Energy Agency. Absorbed dose determination in external beam radiotherapy" Technical Reports Series no. 398 (Rev.1), IAEA, (2024).

[10]. E. E. Klein, J. Hanley, J. Bayouth, F.-F. Yin, W. Simon, S. Dresser, C. Serago, F. Aguirre, L. Ma, B. Arjomandy, C. Liu, C. Sandin, and T. Holmes, "Task Group 142 report: Quality assurance of medical accelerators" Medical Physics, 36, 9, (2009).

[11]. E. B. Podgorsak, "Radiation Oncology Physics: A Handbook for Teachers and Students" International Atomic Energy Agency, (2005).

[12]. P. R. Almond, P. J. Biggs, B. M. Coursey, W. F. Hanson, M. S. Huq, R. Nath, and D. W. Rogers, "Task Group 51 protocol for clinical reference dosimetry of high-energy photon and electron beams" Medical Physics, 26, 9, (1999).