

MEGAVOLTAGE COMPUTED TOMOGRAPHY (MVCT) DOSE ASSESSMENT AT DIFFERENT DEPTHS

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Abstract. The aim of the study is to evaluate the point doses measured by different parameters at various depths with MVCT in the Tomotherapy Hi- Art (HT) treatment unit. HT works in two modes: visual modes and therapy modes. The MVCT images are taken in the visual mode. The user can choose the scan length and image pitch value in the visual mode. The system has pitch values called fine, normal and coarse. When the same volume is scanned during the gantry rotation, the scan times of fine, normal, and coarse modes are different from one another. Cheese Phantom is used to evaluate the point doses. The measured values ranged from 0.64 to 2.67 cGy with an average dose of 1.40cGy. The lowest MVCT dose is found when 7 slices are scanned with a depth of 20 cm for 51 seconds. The highest MVCT dose is found when 17 slices are scanned with a depth of 15 cm for 101 seconds. The measured values are the highest when the fine mode is selected with low depth and high slice. The IGRT method is used before each treatment and can be used more than once if necessary. Therefore, the right mode selection can prevent taking unnecessary doses during MVCT.

Key words: Tomotherapy, MVCT, different depths, dose

1. INTRODUCTION

In recent years, many radiotherapy (RT) devices also have image-guided radiotherapy (IGRT) [1,2]. Tomotherapy Hi-Art (Accuray Inc., Sunnyvale, CA) (HT) is an image-guided, intensity-modulated radiation therapy (IG-IMRT) system that can obtain a megavoltage computed tomography (MVCT) scan prior to each treatment to minimize daily setup variations [3,4,5]. The HT system uses MVCT images for patients initially positioning [6]. MVCT is a sensitive imaging tool that allows anatomical details to be seen. The MVCT system is placed on a ring gantry with a xenon ion-chamber array mounted opposite the radiation source. The accelerator in display 6 MV is tuned to 3.5 MV for the imaging mode [7]. This way, the contrast of the soft tissue can be increased during the MVCT scan [8]. Three modes of MVCT image acquisition: coarse, normal and fine, obtained by different pitches (couch movement per gantry rotation 12, 8 or 4 mm) are available resulting in image reconstruction with inter slice distances of 6, 4 and 2 mm [9]. Daily MVCT datasets are registered to the treatment planning kilo voltage CT (KVCT) dataset using automated and/or manual image-fusion tools [5]. This allows the verification of patient positioning, target and organ at risk's (OAR's) registration to assess the internal motion (volume changes and the geometric shift), and the reconstruction of the delivered dose [10]. There are some disadvantages as well as the advantages of the daily MVCT view. These disadvantages include the

extra doses given to the patient during the procedure and the prolongation of the treatment period [11].

The aim of the study is to evaluate the point doses measured by different parameters at various depths with MVCT in the Tomotherapy Hi – Art (HT) treatment unit.

2. MATERIALS AND METHODS

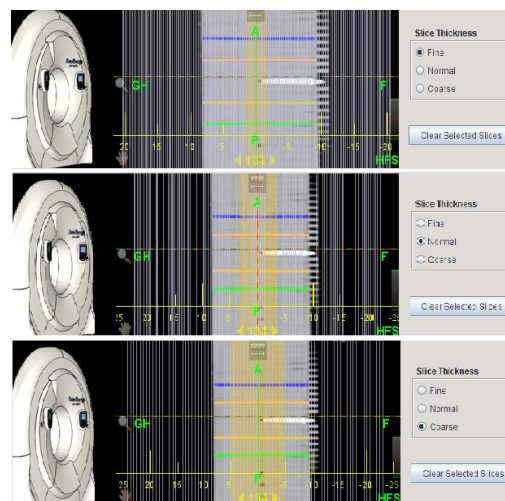


Figure 1. The images of the ion chamber using various pitches (seven slices selected).

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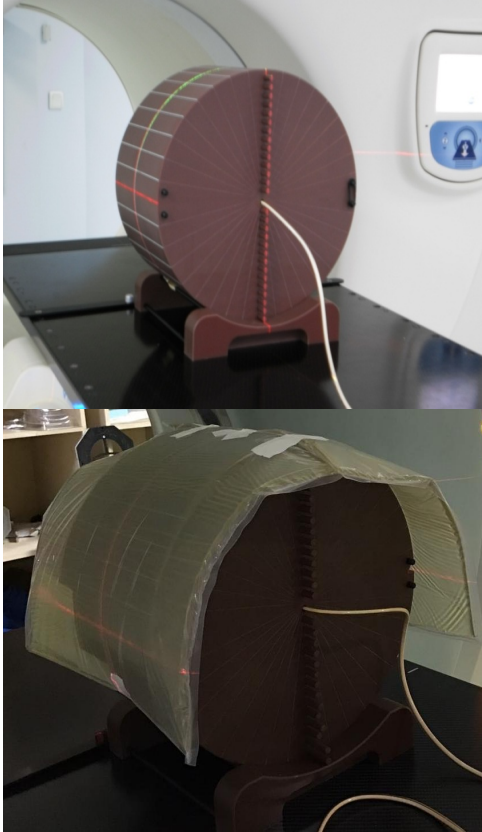


Figure 2. The 'cheese' phantom wrapped with a 0.5cm thickness bolus. Exradin A1SL ion chamber (Standard Imaging, Middleton, WI), which is used to verify the absolute dose. The ionization chamber inserted 0.5 cm below the center of the phantom.

HT is a top-level therapy device with IGRT. The machine works in two modes: visual mode and therapy mode. The nominal amount of energy is 3.5MV and MVCT images are taken in the visual mode. In the visual mode, MVCT images are visually evaluated and registered with the planning KVCT set either manually or automatically. The system turns all MLCs on and the duration of the gantry period is 10 sec in order to obtain an image during MVCT. The HT system presents two parameters to the user in the visual mode. The first is the scan length selection parameter. The desired volume can be scanned this way. The increase in the scan size also means that the scan time increases. Another parameter is to select the image pitch value. This value represents the length of the nominal slice thickness. The system offers 3 different pitch values. These are called Fine (2mm), Normal (4mm) and Coarse (6mm). When the same slice

number is scanned, the fine, normal, and coarse modes' scan length and time are different from one another during the scan (Figure 1).

In this study, point measurements were made at various depths using the Exradin A1SL ion chamber (Standard Imaging, Middleton, WI) connected to TomoElectrometer with Tomotherapy 'cheese' phantom (GammexRMI, Middleton, WI). The cheese is a cylinder of 15 cm in radius and 15 cm in length, with a linear series of holes that extends on one face of the phantom for ionization chamber measurements. Exradin A1SL ion chambers (0.057 cm³) were used in measurements. For all measurements, the phantom was positioned onto the HT treatment couch with the ionization chamber inserts disposed along the sagittal direction (perpendicular to the longitudinal axis of the treatment couch) and the ionization chamber inserted 0.5 cm below the centre of the phantom. The cheese phantom was wrapped with boluses of different thickness (0.5,1, 2,3,4,5 cm) (Figure 2).Boluses of different thickness have been used to obtain different depth measurements. The values read from the electrometer are recorded as Pico Coulomb (PC). The values are calculated according to the required fixed values, the pressure and the temperature of the environment are indicated in Table 1,2 and Figure 2 in terms of CentiGray (cGy).

3. RESULTS

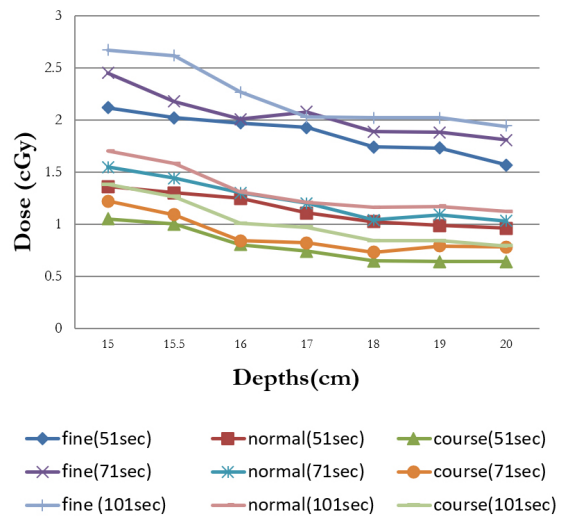


Figure 3. Chart showing measurement dose results at different depths and different mode

Table 1, 2. MVCT dose values obtained at different depths using Cheese Phantom

Scan Mode	Scan Time (sec)	Num. of Slices	Scan Length (cm)	Depth	Depth	Depth	Depth	Depth	Depth
				Dose 15cm pC	Dose 15cm cGy	Dose 15.5cm pC	Dose 15.5cm cGy	Dose 16cm pC	Dose 16cm cGy
Fine	51	7	1.4	30.90	2.12	29.40	2.02	28.73	1.97
Fine	71	11	2.2	35.71	2.45	31.80	2.18	30.63	2.01
Fine	101	17	3.4	38.95	2.67	38.30	2.62	33.25	2.27
Normal	51	7	2.8	19.95	1.36	19.06	1.30	18.21	1.25
Normal	71	11	4.4	22.59	1.55	21.05	1.44	19.02	1.30
Normal	101	17	6.8	24.91	1.70	23.09	1.58	19.15	1.31
Coarse	51	7	4.2	15.39	1.00	14.65	1.00	11.73	0.80
Coarse	71	11	6.6	17.77	1.22	15.86	1.09	12.26	0.84
Coarse	101	17	10.2	20.12	1.38	18.43	1.26	14.76	1.01

Scan Mode	Scan Time (sec)	Num. of Slices	Scan Length (cm)	Depth	Depth	Depth	Depth	Depth	Depth	Depth	
				Dose 17cm pC	Dose 17cm cGy	Dose 18cm pC	Dose 18cm cGy	Dose 19cm pC	Dose 19cm cGy	Dose 20cm pC	Dose 20cm cGy
Fine	51	7	1.4	28.16	1.93	25.59	1.74	25.39	1.73	22.96	1.57
Fine	71	11	2.2	30.35	2.08	27.66	1.89	27.52	1.88	26.36	1.81
Fine	101	17	3.4	29.61	2.03	29.61	2.02	29.56	2.02	28.32	1.94
Normal	51	7	2.8	16.23	1.11	13.94	1.32	14.58	0.99	13.97	0.96
Normal	71	11	4.4	17.50	1.20	15.23	1.04	15.93	1.09	15.06	1.03
Normal	101	17	6.8	17.56	1.21	17.02	1.16	17.05	1.17	16.42	1.12
Coarse	51	7	4.2	10.83	0.74	9.59	0.65	9.47	0.64	9.46	0.64
Coarse	71	11	6.6	12.08	0.82	10.64	0.73	11.66	0.79	11.36	0.78
Coarse	101	17	10.2	14.17	0.97	12.33	0.84	12.35	0.84	11.43	0.79

4. DISCUSSION AND CONCLUSION

MVCT has become a standard imaging tool for patient localization in HT. The imaging dose from MVCT is often ignored relative to the dose used in patient treatment. However, if a high dose protocol is used on a daily basis. This means that an extra high dose is given to the patient during the treatment process. This research shows that once the doses are analyzed, it can be seen that the measured values are highest when the fine mode with low depth and high slice is selected. Similarly measured values are lowest

when the course mode with high depth and low slice is selected.

The image dose is higher in the head and neck than in the pelvis, thorax or abdomen region depending on the tomotherapy procedure used [12,13]. The MVCT doses measured may be different depending on the different screening conditions and different types of phantoms. Xu et al.'s study shows that the MVCT scan dose for the body phantom was between 0.599 and 2.876 cGy, while the dose for the head phantom was between 0.913 and 3.231 cGy during each treatment delivery on the tomotherapy device [14]. In similar studies, the absorbed doses of the organs in the head

and neck and chest region ranged from 1.61-1.89 cGy, while the proportion of organs in the abdomen and pelvis region was between 0.79-1.85 cGy [15, 16]. However, Alaei and Spezi reported that the imaging doses were 4-5 cGy in internal organs and these doses could reach up to 7cGy on the skin [17].

Tissue characterization solid water phantom (or cheese phantom) with multiple ionization chambers is commonly used in HT dose measurement [9]. In this study, cheese phantom was used for MVCT dose measurements and the measurement results showed that the average dose was 1.40 cGy. Similar results were emphasized in other studies. Shah et al. found that the typical imaging dose is approximately 1.5 cGy per imaging HT [18]. Kupelian and Langen's study showed that for the 'normal' MVCT scan mode, the MVCT dose ranged from 1 to 1.5 cGy per scan [13]. When the perfusion imaging doses of the different IGRT modalities were examined, doses ranged from portal devices 1-10 cGy, kV Cone-beam CT(KV-CBCT) 2-3 cGy, MVBCT 5-15 cGy, kVFan-Beam CT (kV-FBCT) 0.8-2.8 cGy [19,20,21]. A number of other reports show that the patient's dose was measured as 0.5-3.0 cGy during the MVCT scan in the HT device [12, 16, 22, 23].

The MVCT scans can be acquired in fine, normal and coarse modes. In this study, the lowest MVCT dose is found when scanned in the coarse mode and the highest MVCT dose is found when scanned in the fine mode (coarse mode dose 0.64cGy, fine mode dose 2.67cGy). Similarly, Kupelian and Lange found that the fine mode MVCT dose was greater than the normal and coarse mode (coarse mode dose was 0.7cGy, fine mode dose was 3cGy) [13]. Chan et al., in their study was used to cylindrical water phantoms of various diameters for various scanning parameters, including 3 different jaw openings) and couch speeds (fine, normal, and coarse). They have reached 3.1cGy dose with different jaws in fine mode [24].

In our study, the same protocol was used for different depth measurements. In measurements obtained using the same protocol, higher doses were found at a lower depth. Studies have shown that oversized patients receive significantly higher doses than thin patients during imaging [25]. Protocol selection for thin and oversized patients should be different from each other. This way, better image quality can be obtained.

Another important factor is the timing of patient imaging. In this study, the screening times were 51, 71 and 101 sec. The scan time may change depending on the scan size and selected treatment mode. In different imaging systems, imaging times are on average 0.1-3 min in portal devices, 2-4 min in KV- CBCT, 2-3 min in MV-CBCT and 15 min in KV FBCT. The average imaging time is 2-3 min in tomotherapy [19,20]. The duration of imaging should be calculated taking into consideration the patient size and condition.

The IGRT method should be applied according to clinical targets. The image quality is MVCT if the soft tissue contrast is lower than KCVT [23]. Before selecting the imaging mode, it should be assessed whether the irradiation region is a bone structure or

soft tissue. All these evaluations are important for the awareness of pre-imaging.

The IGRT method is used before each treatment and can be used more than once if necessary in the HT device. This study is simulation experiment for visualization of the differences between MVCT doses resulted from changing the size of phantom by helical methods of dose delivery. As a result, it is important to use the best scanning mode for prevent taking unnecessary MVCT doses.

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