 

# COMPARISONS OF IMAGING DOSE AMONG DIFFERENT IMAGING MODALITIES IN RADIATION THERAPY

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## ABSTRACT

**Purpose:** In radiation therapy, x-ray imaging procedures in both computed tomography (CT) simulation and image-guided radiation therapy (IGRT) add radiation dose to patients, which may pose an increased risk to patients. In our institution and affiliated local VA hospital, the Varian Trilogy cone beam CT (CBCT) and Elekta Synergy X-ray volumetric imaging system (XVI), along with GE light-speed and Philips Brilliance CT simulators are applied in the radiation treatment. This study evaluated the imaging doses from different imaging modalities and devices.

**Methods:** The imaging dose was measured using a CT dose index (CTDI) phantom and Unfors Xi pencil ionization chamber for both peripheral and central locations. The measurements were performed and compared between Varian Trilogy kV 3D CBCT and Elekta Synergy 3D kV XVI based on our clinical protocols for pelvis with a comparable image quality. Additionally, the 4D and 3D XVI imaging doses were measured and compared on an Elekta Synergy XVI system. The CT imaging doses were measured and compared between GE light-speed RT16 and Philips Brilliance 16-slice CT simulators.

**Results and Conclusions:** Imaging dose differences were determined between different imaging modalities by using the CTDI method in this study. The results show that the kV CBCT imaging dose is lower for Elekta Synergy XVI compared to Varian Trilogy. The 4D XVI imaging dose is higher at the top peripheral location of the CTDI phantom compared to 3D XVI for Elekta Synergy. Furthermore, GE light-speed CT adds higher imaging doses for both 3D and 4D image modalities compared to Philips Brilliance counterparts. Although the imaging dose difference exists among the different imaging modalities, it is worth noting that the imaging dose was in the range nationally reported.

**Key Words:** Radiation Therapy, Image-guided Radiation Therapy (IGRT), Computed Tomography (CT), Cone Beam CT (CBCT), X-ray Volumetric Imaging System (XVI), CT Dose Index (CTDI), Imaging Dose

## INTRODUCTION

Image-guided radiation therapy (IGRT) is the use of imaging during radiation therapy to improve the precision and accuracy of treatment delivery.[1] Radiographic image guidance is the current standard of care for patient positioning, target localization, and external beam alignment in radiation therapy,[2] which however can give a significant radiation dose to the patient in addition to the prescribed dose and should be carefully managed and monitored as low as reasonably achievable, rather than considered as negligible or quantified in a fairly loose manner.[3] Currently, the commonly used x-ray image devices in radiation therapy include CT simulators such as the Philips Brilliance Big Bore and the GE Light-speed RT 16; two dimensional (2D) MV electronic portal imaging device (EPID) and three dimensional (3D) kV-cone beam computed tomography (CBCT) integrated to treatment unit. Recently, four dimensional (4D) CBCT has become clinically available. This study compared the imaging doses from different imaging procedures in our institute using CTDI method. In concept, the CTDI is to measure the integral dose along an infinite length of a static scan. However, in practical, the $CTDI_{100}$, which integrates a length of 10 cm is accepted as a standard for CT dose measurement by many national and international organizations. [4] The $CTDI_{100}$ is measured in a phantom that is 15 cm in length and either 32 cm in diameter for body or 16 cm in diameter for head (see Figure 1) with 100 mm long pencil ionization chamber. [5]

## METHODS

Figure 1 demonstrates the imaging dose measurement set up using Unfors Xi system with 100 mm ionization chamber and CTDI phantom. CTDI phantom were placed on the couch of a Varian linac as an example. The image dose ($CTDI_{100}$) were measured using Unfors Xi and at five different locations. CTDI chamber locations 1, 2, 3, 4, and 5 represent the locations of Center, Top, Bottom, Right and Left inserts of the CTDI phantom. The center was aligned with the linac iso center. Our routine clinical image protocols listed in Table 1 were used for the image dose measurement on the CTDI phantom. Then with the same set up, the image doses ($CTDI_{100}$) were measured on different linacs (Varian and Elekta) and different CTs (Philips Brilliance Big Bore CT with 16 multi-slice capabilities and GE light speed) with both three-dimensional (3D) and four-dimensional (4D) protocol when available, as it was not with the Varian CBCT system. Only two imaging doses at CTDI chamber locations 1 and 2, which represent center and top inserts of the CTDI phantom were measured for the two CT simulators due to the cylindrical and symmetric gantry of CT.

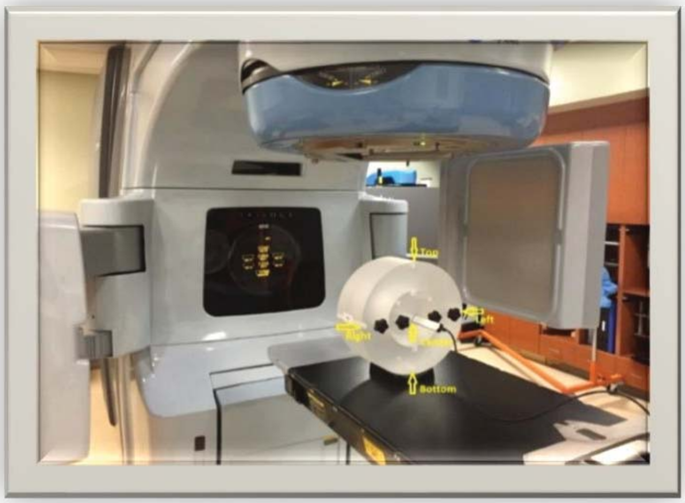



**Figure 1:** Imaging dose measurement set up using Unfors Xi and CTDI phantom

**Table 1**: Imaging dose measurement protocols used in routine clinical procedure

| | Trilogy | Synergy |
|---|---|---|
| **3D CBCT/XVI** | 125 kVp, 80 mAs | 120 kVp, 40 mAs |
| **4D XVI** | Not included in this study | 120 kVp, 300 mAs |
| | **GE Lightspeed** | **Philips Brilliance** |
| **3D CT** | 140 kVp, 50 mAs | 120 kVp, 30 mAs |
| **4D CT** | 140 kVp, 400 mAs | 120 kVp, 400 mAs |

ISSN:0067-8856 01 55 1

978-1-775245-6-8

# RESULTS

Figure 2 shows the imaging dose ($CTDI_{100}$) comparisons between Varian Trilogy CBCT and Elekta Synergy XVI. It can be seen that the XVI imaging dose is lower for Elekta Synergy. Figure 3 compares the image doses between different image modalities of 3D and 4D XVI on Elekta Synergy. It illustrates the 4D XVI image dose is higher at the peripheral location of the CTDI phantom compared to 3D XVI. Figure 4 and 5 compares the CT imaging doses between GE Light-speed RT 16 CT and Philips Brilliance Big Bore for both 3D and 4D modalities respectively. It shows GE Light-speed CT adds higher imaging doses for both 3D and 4D image modalities.

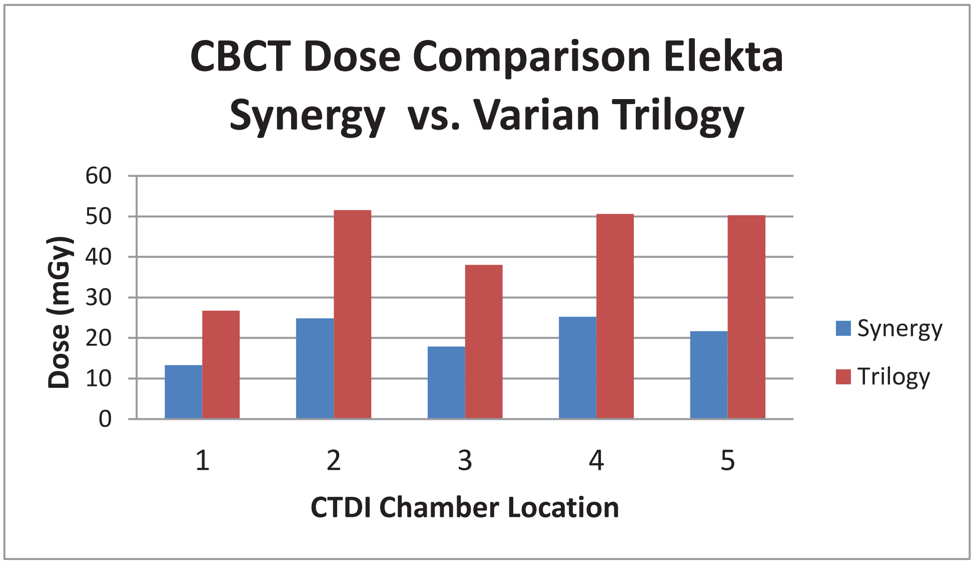



**Figure 2**: Imaging dose comparisons between Varian Trilogy CBCT and Elekta Synergy XVI

CTDI chamber locations 1, 2, 3, 4, and 5 represent the locations of Center, Top, Bottom, Right and Left

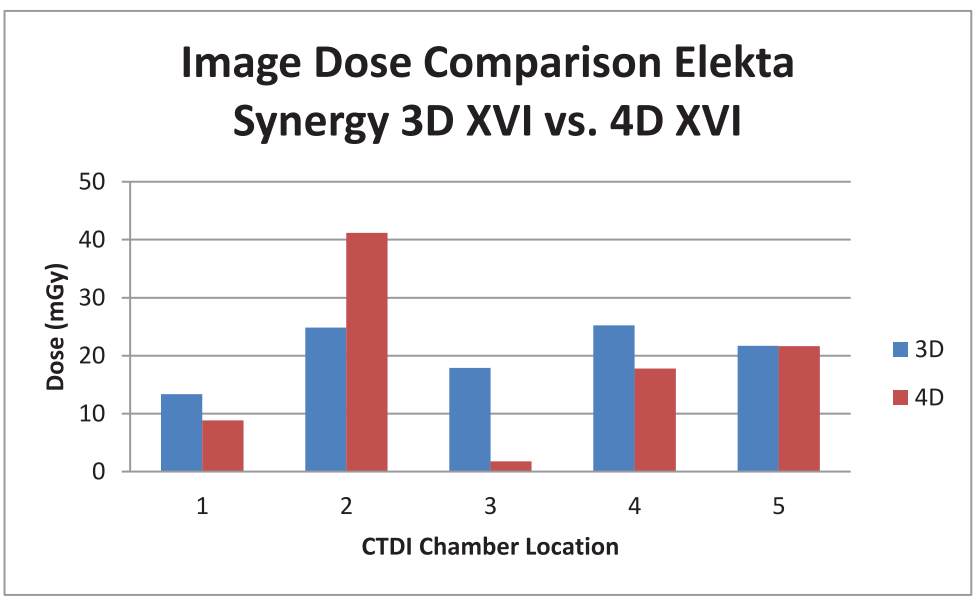



**Figure 3**: Image doses between different image modalities of 3D and 4D XVI on Elekta Synergy CTDI chamber locations 1, 2, 3, 4, and 5 represent the locations of Center, Top, Bottom, Right and Left

**Figure 4**: 3D CT imaging doses between GE Light-speed RT 16 CT and Philips Brilliance Big Bore CTDI chamber locations 1, and 2 represent the locations of Center and Top.

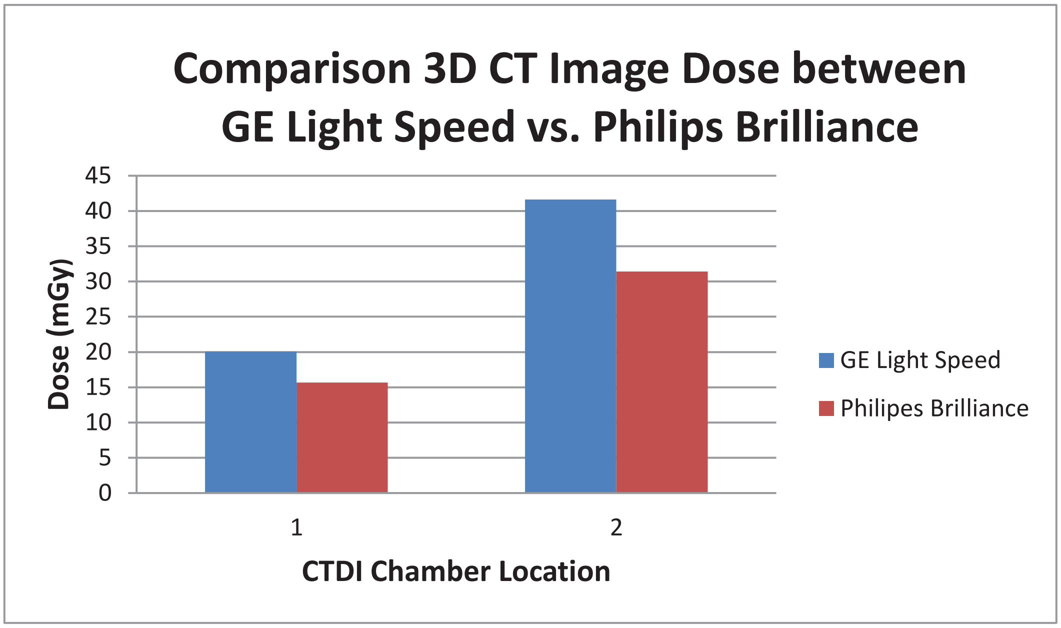
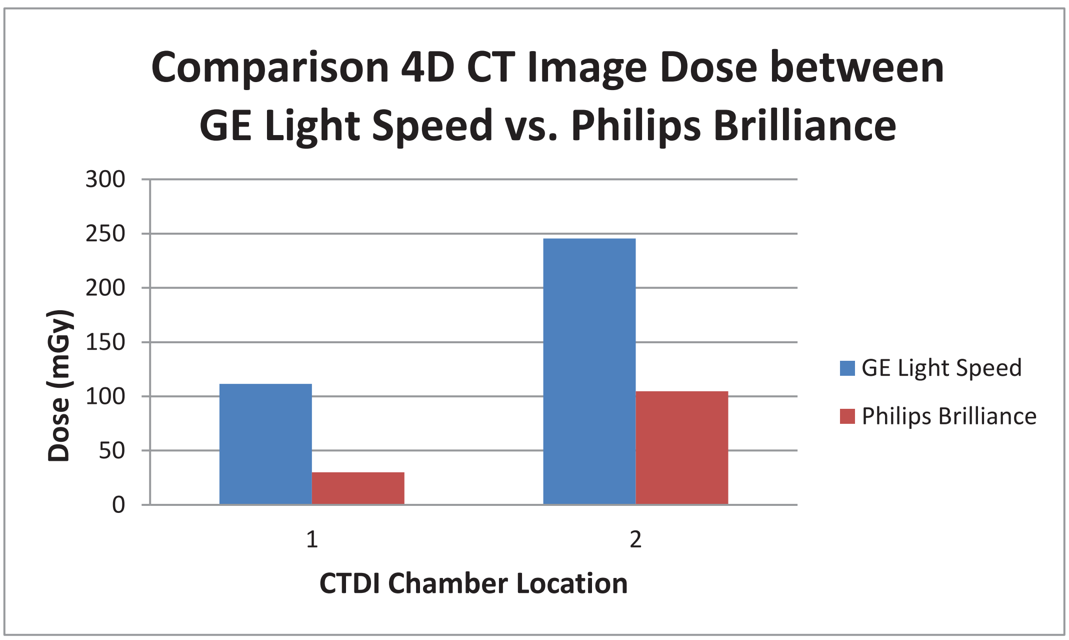



**Figure 5**: 4D CT imaging doses between GE Light-speed RT 16 CT and Philips Brilliance Big Bore CTDI chamber locations 1 and 2 represent the locations of Center and Top.



# DISCUSSIONS

Imaging dose in radiation therapy, both for treatment planning and patient treatment position verification, was insignificant and ignored traditionally since the imaging dose was much smaller compared to therapeutic dose delivered to the patients.[6] However, with the implementation of volumetric imaging modalities and their increased use, imaging dose in radiation therapy has become more of an issue recently.[6] The imaging dose may exceed the linac leakage several times higher in magnitude and it is also throughout over the entire scanning volume, not only targeted on the tumor volume. Additionally, the dose to bone may be up to three times higher than the dose to the soft tissue, etc.[7] Therefore, the increased attention of imaging dose is brought up to many clinicians, medical physicists and investigators. Two American Association of Physicists in Medicine (AAPM) Task Group reports, TG-180 [8] and TG-75[2], were developed and discussed regarding to the concerns and management associated with additional imaging dose to the cancer patients. In June 2018, AAPM organized a summer school with the focus on "Image Guidance in Radiation Therapy: Techniques, Accuracy, and Limitations" [9]. Guidance and overview of imaging dose management, measurements and calculations can be found in this meeting proceeding.[9] This study reported the imaging doses from different imaging modalities in our institute using CTDI method. The imaging doses were measured and significant differences were determined among different imaging modalities in our institute. The dose in our institute delivered by planning 3D CT ranges from 15 to 40 mGy; 4D CT ranges from 30 to 250 mGy and kV CBCT/XVI ranges from 10 to 50 mGy were determined, which are in the range nationally reported. [7]

The CTDI method is generally and traditionally accepted as a standard for CT dose measurement, [9] however, it is not a direct measurement of patient dose. [10] Patient imaging dose measurement is a complex procedure and involves many uncertainties, e.g. patient physical size, tumor location, CBCT/XVI protocol used, measurement technique and tools, etc. The International Atomic Energy Agency (IAEA) has published an update on the status of imaging dose for CT and cone-beam CT scanners [11]. The AAPM task group III report [12] presents their recommendations and practicalities of measuring imaging dose in radiation therapy. However, neither are ideal solutions, and it is not clear which should be used by the practicing medical physicists. [5]

# CONCLUSIONS

Imaging dose were measured and significant differences were determined between different imaging modalities by using the CTDI method in this study. Although the significant differences of the imaging dose among different imaging modalities exists, the imaging doses for different modalities in our institute were determined to be in the range nationally reported. It is very difficult to evaluate the radiation risk from imaging dose to patients clinically, however, it is worthwhile to monitor imaging dose in radiation therapy, which should be optimized, monitored and minimized as low as reasonably achievable. IGRT is a powerful radiation therapy method that incorporates imaging techniques during each treatment session. It uses high-energy beams of radiation to control cancer or noncancerous tumors. By adding detailed images, IGRT ensures the powerful radiation is narrowly focused at the treatment area; therefore, IGRT may make it possible to use higher doses of radiation. This may increase the chance of tumor control, which most likely to result in shorter treatment schedule. Ultimately, the results suggest that these observations may reduce the risk of side effects and become convenient treatment technique for cancer patients.

# DISCLOSURES

The authors declare that no conflict of interest exists.

# REFERENCES

[1] Https://www.radiologyinfo.org/en/info.cfm?pg=igrt

[2] Murphy et al. 2007. The management of imaging dose during image-guided radiotherapy: Report of the AAPM TaskGroup 75. Med. Phys. Vol. 34, No. 10.

[3] Alaei, P et al. 2010. Inclusion of the Dose from Kilovoltage Cone Beam CT in the Radiation Therapy Treatment Plans. Med. Phys. 37(1): 244. Doi:10.1118/1.3271582.

[4] Kim, S., H.Song, et al 2011. Computed Tomography Dose Index and Dose length Product for Cone-Beam CT: Monte Carlo Simulations of a Commercial System. J. Appl. Clin. Med. Phys. 12(2): 84-95.

[5] Jonathan R. Sykes and Robin Hill 2007. Measurement of Kilovoltage imaging Dose: Techniques, Accuracy, andLimitations: AAPM Monograph No. 39

[6] Parham Alaci and Emiliano Spezi 2018. Imaging dose in radiation therapy: Chapter 8 in AAPM summer school Monograph No. 39.

[7] Patrick N. McDermott and Colin G. Orton 2010. The Physics & Technology of Radiation Therapy: Second edition, medical physics publishing.

[8] Ding GX, Alaei P et al 2018: Image guidance doses delivered during radiotherapy: Quantification, management, andreduction: Report of the AAPM Therapy Physics Committee Task Group 180. Med Phys. 2018 May;45(5):e84-e99. doi: 10.1002/mp.12824. Epub.

[9] Parham Alaei and George X. Ding 2018. Image Guidance in Radiation Therapy: Techniques, Accuracy, and Limitations: AAPM Monograph No. 39

[10] Cynthia H et al. 2011. CT Dose Index and Patient Dose: They Are Not the Same Thing: Radiology; 259(2): 311-316.

[11] The IAEA Human Health Reports No. 5, http://www.iaea.org/Publications/index.html.

[12] Robert L. Dixon et al. 2010. The Future of CT Dosimetry: Report of the AAPM Therapy Physics Committee Task Group III. ISBN: 978-1-888340-94-5, ISSN: 0271-7344, © 2010 by American Association of Physicists in Medicine.