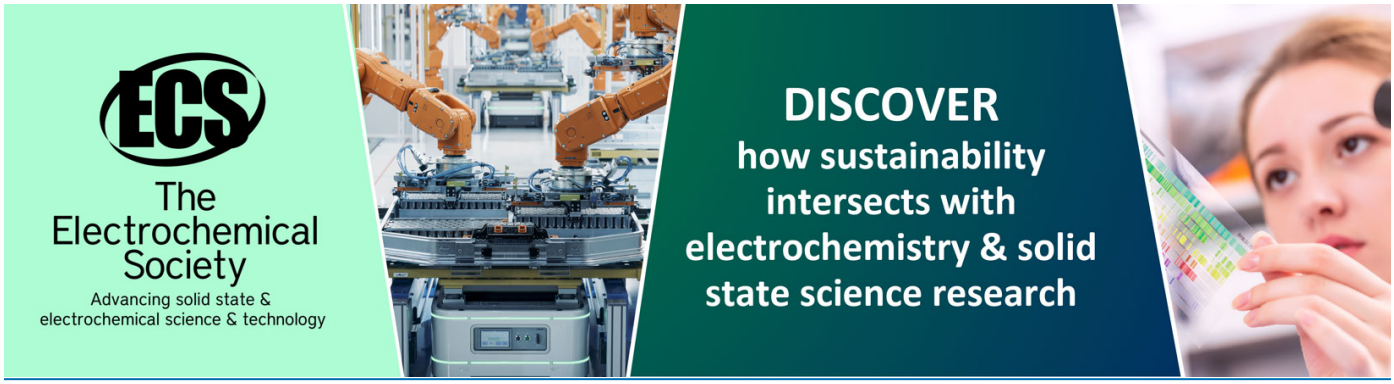
Commissioning and validation of COMPASS system for VMAT patient specific quality assurance



Commissioning and validation of COMPASS system for VMAT patient specific quality assurance

J Pimthong[1], C Kakanaporn[2], L Tuntipumiamorn[2], P Laojunun[2] and P Iampongpaiboon[2]

[1] Medical Physics School, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand
[2] Division of Radiation Oncology, Department of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

E-mail: iamjeerawat@hotmail.com

Abstract. Pre-treatment patient specific quality assurance (QA) of advanced treatment techniques such as volumetric modulated arc therapy (VMAT) is one of important QA in radiotherapy. The fast and reliable dosimetric device is required. The objective of this study is to commission and validate the performance of COMPASS system for dose verification of VMAT technique. The COMPASS system is composed of an array of ionization detectors (MatriXX) mounted to the gantry using a custom holder and software for the analysis and visualization of QA results. We validated the COMPASS software for basic and advanced clinical application. For the basic clinical study, the simple open field in various field sizes were validated in homogeneous phantom. And the advanced clinical application, the fifteen prostate and fifteen nasopharyngeal cancers VMAT plans were chosen to study. The treatment plans were measured by the MatriXX. The doses and dose-volume histograms (DVHs) reconstructed from the fluence measurements were compared to the TPS calculated plans. And also, the doses and DVHs computed using collapsed cone convolution (CCC) Algorithm were compared with Eclipse TPS calculated plans using Analytical Anisotropic Algorithm (AAA) that according to dose specified in ICRU 83 for PTV.

1. Introduction

The goal of radiotherapy is to deliver as much dose to the tumor while sparing normal tissue. In advanced radiotherapy techniques, volumetric modulated arc therapy (VMAT) is one of the techniques have helped achieve this goal. The VMAT produces highly conformal dose distribution while simultaneously sparing the organs at risk (OAR), for several indications potentially with a further shortening of treatment times [1, 2]. With this technology, it is possible to deliver an intensity modulated treatment in the form of arcs by dynamically controlling various parameters such as position and speed of the gantry and multi –leaf collimator (MLCs) as well as dose rate [3]. However, with the complexities of treatment deliveries, a comprehensive pre-treatment patient specific quality assurance (QA) procedure is required. Pre-treatment patient specific QA in radiotherapy is the method used to ensure that the correct amount of radiation is being delivered to the correct location. It is a comparison between calculated radiation dose in treatment planning system and radiation dose from

measuring. Advanced treatment techniques such as VMAT require appropriate pre-treatment QA to verify 3D dose distribution [4]. The fast and reliable dosimetric device also is required.

A traditionally routine QA method for treatment plan verification is performed in a phantom using small volume ion chambers for absolute dosimetry [5] or radiographic film for relative dosimetry [6] are time consuming. Recently two-dimensional (2D) array and electronic portal imaging device (EPID) show the dose distribution immediately after the treatment delivery. Currently, our department has used commercially two-dimensional (2D) detector arrays, MapCHECK diode array (Sun nuclear, Melbourne, Florida, USA) for the quality assurance of patient-specific IMRT and VMAT treatment plans. To evaluate the treatment plan, gamma index passing rate is usually used in criteria of 95% gamma pass ($\gamma \leq 1$). Due to the lack of information about the correlations between the verification measurement results and the patient anatomical structures. And also the resulting lack of information about the actual irradiation doses to the different target volume and organ at risk. Recently some 3D verification tools that provide patient anatomical structure information were applied clinically. The COMPASS QA system (IBA Dosimetry, Germany) is one such technique which uses MatriXX detector (IBA Dosimetry, Schwarzenbruck, Germany) along with gantry angle sensor. It consists of two parts; COMPASS software and an associated measuring device [7]. COMPASS software is able to recalculate and to reconstruct a 3D dose distribution on the CT data of the patient based on measured fluence from MatriXX detector of the patient based on measured fluence from MatriXX detector and collapsed cone convolution/superposition algorithm. Therefore, the aim of the present study is to validate the accuracy of the COMPASS system by comparing computation dose and reconstruction dose in each VMAT plan of prostate cancer and nasopharyngeal cancer radiation dose from the TPS. The doses and DVHs computed using Collapsed Cone Convolution (CCC) Algorithm were compared with Eclipse TPS calculated plans using Analytical Anisotropic Algorithm (AAA) that according to dose specified in ICRU 83 for PTV.

2. Material and methods

To commission the COMPASS system, reformatting 6 and 10 MV photon beam data from a Varian Clinac iX linear accelerator (Varian Medical Systems, Palo Alto) into a software acceptable beam model was required. The COMPASS system is composed of an array of ionization detectors (MatriXX) mounted to the gantry using a custom holder and software for the analysis and visualization of QA results. Furthermore, the validation of COMPASS software was studied in two aspects; the basic application and advanced application studies. To study the basic application, the homogeneous phantom was employed. For the advanced application, fifteen prostate cancer and nasopharyngeal cancer VMAT plans using 10 MV and 6 MV photons respectively were chosen to investigate. The MatriXX detector was performed in warm-up phase for 15 minutes, then was pre-irradiated at dose 10 Gy at the beginning with an open field size of 25 × 25 cm^2 for SDD = 100 cm. Next, performed the geometry calibration step with an open field size of 10 × 10 cm^2, with 100 MU delivered. The absolute calibration (cGy/MU) was measured with an open field size of 10×10 cm^2, with 100 MU delivered. Lastly, performed calibration gantry angle sensor and then the gantry angle sensor was tested if the calibration of the sensor is still inside accuracy criteria. To generate the dose calculation from COMPASS software, the DICOM files of each treatment plan (RT plans, RT doses, RT structures and CT images) was exported to the COMPASS software (version 3.0a, IBA Dosimetry GmbH, Schwarzenbruck, Germany) with an associated measuring device, the MatriXX detector. The MatriXX was attached on the gantry with gantry holder. The solid water phantoms (Gammex RMI GmbH, Germany) were placed on a surface of MatriXX detector as build up material 2.0 cm and 5.0 cm thickness for 6 and 10 MV photon beam, respectively.

2.1. Basic clinical application study

The aim of the basic clinical study was to verify the accuracy of the COMPASS® software; the simple open field in various sizes were validated in homogeneous phantom. Firstly**,** the homogeneous water phantom of size 30 × 30 cm^3 was created and then a 3.5 × 3.5 cm^3 PTV1, 4.0 × 4.0 cm^3 PTV2 and 4.5

× 4.5 cm^3 PTV3 were created at the center of the homogeneous water phantom. The fluence for open fields in various sizes of 5 × 5, 5 × 10, 10 × 10, 15 × 15, 20 × 20, 20 × 5 and 25 × 25 cm^2 at 100 cGy Prescribed dose for 6 MV and 10 MV were acquired by the COMPASS® software on a homogeneous phantom that was created in Eclipse TPS**.** Afterward, the dose calculated and measured by COMPASS QA system and Eclipse TPS respectively were compared. The doses and DVHs computed using collapsed cone convolution (CCC) Algorithm were compared with Eclipse TPS calculated plans using analytical anisotropic algorithm (AAA) that according to dose specified in ICRU 83 for PTV.

2.2 Advanced clinical application study

According to the aim of this study is to clinically implement the COMPASS® software for pre-treatment QA of VMAT treatment plans. The fifteen prostate cancer and nasopharynx cancer VMAT plans were chosen to investigate. To generate DVHs using COMPASS software, the fluence from MatriXX measurement were transferred to the software. The output of the COMPASS software gave 3D dose reconstruction on patient CT images using beam modeling, detector measurement and TPS. The DVHs were compared between the COMPASS® dose reconstruction and Eclipse TPS dose calculation according to dose specified in ICRU 83 for PTV and OARs. The DVHs analysis of Planning Target Volume (PTV).

3. Results

3.1. Basic clinical application study

For basic clinical application study, to verify the accuracy in dose computation of COMPASS software which an independent secondary treatment planning check to verify conventional TPS calculation. The doses were analyzed by the definition of $D_{98\%}$, $D_{95\%}$, $D_{50\%}$, $D_{2\%}$ and average dose in each PTV. The results showed that the calculated dose difference between COMPASS software and TPS was less than 2%. In addition, the measured dose and reconstruction dose from COMPASS was differed from TPS dose less than 3%.

3.2 Advanced clinical application study

The advanced clinical application study for the prostate cancer and nasopharyngeal cancer VMAT plans, the comparison of DVHs between TPS calculated dose and computed dose from COMPASS software was evaluated in term of $D_{98\%}$, $D_{95\%}$, $D_{50\%}$, $D_{2\%}$ and average dose of PTV at tolerance level of 3%, the results showed that the mean of percentage difference was 0.19%, 0.13%, 0.11%, 0.16% and 0.11%, respectively are shown in table 1(a). For the nasopharyngeal cancer VMAT plans, the results showed that the mean of percentage difference was 1.85%, 1.87%, 1.61%, 0.76% and 1.55%, respectively are shown in table 2(a).

For the prostate cancer VMAT plans, the comparison of DVHs between TPS and reconstructed dose from COMPASS software was also evaluated. The results showed that the mean of percentage difference was 2.55%, 1.65%, 0.18%, 0.73% and 0.25%, respectively are shown in Table 1(b). For the nasopharyngeal cancer VMAT plans, the results showed that the mean of percentage difference was 2.87%, 2.35%, 1.23%, 0.87% and 1.17 %, respectively are shown in table 2(b).

Table 1. (a) Comparison of COMPASS computed and Eclipse calculated for prostate cancer (10 MV) (b) Comparison of COMPASS measured and Eclipse calculated for prostate cancer (10 MV).

(a)

Site	$D_{98\%}$	$D_{95\%}$	$D_{50\%}$	$D_{2\%}$	Average
	Absolute Relative Difference (%)				
Prostate1	0.10	0.00	0.10	0.00	0.10
Prostate2	0.10	0.20	0.00	0.20	0.10
Prostate3	0.20	0.00	0.00	0.10	0.00
Prostate4	0.40	0.30	0.10	0.20	0.20

(b)

Site	$D_{98\%}$	$D_{95\%}$	$D_{50\%}$	$D_{2\%}$	Average
	Absolute Relative Difference (%)				
Prostate1	2.30	1.50	0.00	0.80	0.10
Prostate2	2.80	1.40	0.60	1.40	0.40
Prostate3	3.40	2.20	0.10	0.60	0.30
Prostate4	2.50	1.80	0.00	0.70	0.20

Prostate5	0.40	0.30	0.20	0.30	0.20	Prostate5	3.00	2.20	0.10	0.40	0.40
Prostate6	0.20	0.20	0.30	0.10	0.20	Prostate6	2.50	1.60	0.30	0.30	0.40
Prostate7	0.00	0.10	0.10	0.10	0.00	Prostate7	3.00	1.80	0.10	0.60	0.10
Prostate8	0.60	0.40	0.20	0.20	0.20	Prostate8	2.60	1.90	0.10	0.70	0.30
Prostate9	0.10	0.10	0.00	0.10	0.00	Prostate9	2.80	1.70	0.30	0.30	0.50
Prostate10	0.10	0.10	0.00	0.10	0.00	Prostate10	1.40	0.90	0.10	0.70	0.10
Prostate11	0.20	0.10	0.30	0.30	0.30	Prostate11	2.30	1.40	0.10	0.80	0.10
Prostate12	0.30	0.00	0.00	0.50	0.00	Prostate12	3.20	2.40	0.50	0.40	0.60
Prostate13	0.00	0.00	0.10	0.20	0.10	Prostate13	1.70	1.20	0.10	1.20	0.10
Prostate14	0.00	0.00	0.20	0.00	0.10	Prostate14	2.40	1.30	0.10	0.90	0.10
Prostate15	0.20	0.20	0.10	0.00	0.10	Prostate15	2.40	1.50	0.20	1.20	0.00
Average	0.19	0.13	0.11	0.16	0.11	Average	2.55	1.65	0.18	0.73	0.25

Table 2. (a) Comparison of COMPASS computed and Eclipse calculated for NPC (6 MV) (b) Comparison of COMPASS measured and Eclipse calculated for NPC (6 MV)

(a)

Site	$D_{98\%}$	$D_{95\%}$	$D_{50\%}$	$D_{2\%}$	Average
	Absolute Relative Difference (%)				
NPC1	1.00	1.20	1.60	1.70	1.60
NPC2	1.70	1.60	1.20	0.70	1.30
NPC3	1.70	1.90	1.50	1.50	1.60
NPC4	1.50	1.40	1.50	0.40	1.30
NPC5	1.80	1.70	1.40	1.10	1.40
NPC6	1.40	1.30	1.30	0.40	1.20
NPC7	1.90	1.70	1.60	1.00	1.50
NPC8	3.00	2.40	1.40	0.40	1.60
NPC9	1.90	2.00	1.50	0.70	1.40
NPC10	2.10	2.20	2.10	0.30	1.90
NPC11	2.00	2.30	1.60	0.00	1.50
NPC12	1.60	1.90	1.90	1.10	1.70
NPC13	2.70	2.50	2.20	0.80	2.10
NPC14	2.00	1.90	1.80	0.60	1.70
NPC15	1.40	2.00	1.50	0.70	1.50
Average	1.85	1.87	1.61	0.76	1.55

(b)

Site	$D_{98\%}$	$D_{95\%}$	$D_{50\%}$	$D_{2\%}$	Average
	Absolute Relative Difference (%)				
NPC1	3.10	2.60	1.70	0.80	1.70
NPC2	3.20	2.30	1.50	0.10	1.50
NPC3	2.80	2.40	1.20	0.60	1.40
NPC4	3.90	2.50	1.00	1.20	0.90
NPC5	3.30	2.60	1.50	0.70	1.60
NPC6	2.00	1.40	0.90	1.40	0.60
NPC7	2.50	2.00	1.00	0.60	0.90
NPC8	3.50	2.70	1.00	1.40	1.10
NPC9	1.80	1.50	0.10	0.80	0.20
NPC10	3.80	3.40	1.90	0.80	1.70
NPC11	2.60	2.50	1.30	0.50	1.20
NPC12	2.00	1.90	1.10	0.70	1.00
NPC13	2.60	2.10	1.30	2.10	1.00
NPC14	3.10	2.50	1.20	0.60	1.20
NPC15	2.80	2.80	1.70	0.70	1.50
Average	2.87	2.35	1.23	0.87	1.17

4. Discussion

In this study, the COMPASS computed DVHs with Eclipse TPS calculated DVHs for fifteen nasopharyngeal cancers as well as fifteen prostate cancers were compared and shown good agreement with the comparison between the COMPASS system and Eclipse TPS, the results showed that the percent difference between COMPASS computed and Eclipse TPS calculated DVHs was less than 2%. And the percent difference between the COMPASS measured and Eclipse TPS calculated dose was less than 3%. Such difference may be due to the difference in beam modeling and inhomogeneity corrections between two different calculation algorithms, Collapsed Cone Convolution in COMPASS system and AAA in Eclipse TPS. Another reason it may be due to the difference resolution in MatriXX 2D detector array and Eclipse TPS grid calculation. Although, the dose measured from COMPASS and TPS expected dose distribution differed, it showed less than 3% which is acceptable. Therefore, it is recommended to use other traditional pretreatment QA such as film and absolute dose measurement by ionization chamber accompanied with the COMPASS software to confirm the results.

5. Conclusion

In conclusion, the COMPASS QA system is able to perform a full three-dimensional Collapsed Cone Convolution/Superposition algorithm, whereas the Eclipse TPS uses Analytical Anisotropic Algorithm (AAA) to generate calculated dose. The results in this study showed that the percentage difference of the dose between COMPASS software and TPS calculation was less than 2% in order to be analyzed by the definition of $D_{98\%}$, $D_{95\%}$, $D_{50\%}$, $D_{2\%}$ and average dose in each PTV. Moreover, the dose measured from COMPASS and TPS expected dose distribution was differed less than 3%. Taken all together, it indicated that using COMPASS QA system along with Matrix Detector (IBA dosimetry) can be an effective tool for 3D dose pre-treatment verification of VMAT plans in the patient anatomy when compared to traditional TPS.

References

[1] Wolff D *et al*. 2009 Volumetric modulated arc therapy (VMAT) vs. serial tomotherapy, step-and-shoot IMRT and 3D-conformal RT for treatment of prostate cancer *Radiother. Oncol.* **93** 226-33

[2] Palma D, Vollans E, James K, Nakano S, Moiseenko V, Shaffer R, McKenzie M, Morris J and Otto K 2008 Volumetric modulated arc therapy for delivery of prostate radiotherapy: comparison with intensity modulated radiotherapy and three dimensional conformal radiotherapy *Int. J. Radiat. Oncol. Biol. Phys.* **15** 996-1001

[3] Yu C X 1995 Intensity-modulated arc therapy with dynamic multi-leaf collimation: an alternative to tomotherapy *Phys. Med. Biol.* **40** 1435-49

[4] Boggula R, Jahnke L, Wertz H, Lohr F and Wenz F. 2011 Patient-specific 3D pre-treatment and potential 3D online dose verification of Monte Carlo-calculated IMRT prostate treatment plans *Int. J. Radiat Oncol. Biol. Phys.* **81** 1168-75

[5] Yoda K, Nakagawa K, Shiraishi K, Okano Y, Ohtomo K and Pellegrini R G 2009 Dose verification of intensity modulated arc therapy using an ERGO treatment planning system and Elekta internal multi-leaf collimators for prostate cancer treatment *Br. J. Radiol*. **82** 328–31

[6] Ezzell G A, Galvin J M, Low D, Palta J R, Rosen I, Sharpe M B, Xia P, Xiao Y, Xing L and Yu C X 2003 Guidance document on delivery, treatment planning and clinical implementation of IMRT: report of the IMRT Subcommittee of the AAPM Radiation Therapy Committee *Med. Phys*. **30** 2089-115

[7] IBA Dosimetry 2011 *COMPASS Manual* Germany GmbH