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Original research article

Validation of Dolphin dosimetry in three dimensional patient-specific quality assurance programme

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ABSTRACT

Aim: The aim of this study is to commission and validate Dolphin-Compass dosimetry as a patient-specific Quality Assurance (QA) device.
Background: The advancement of radiation therapy in terms of highly conformal delivery techniques demands a novel method of patient-specific QA. Dolphin-Compass system is a dosimetry solution capable of doing different QA in radiation therapy.
Materials and methods: Dolphin, air-vented ionization detector array mounted on Versa-HD Linear Accelerator (LINAC) was used for measurements. The Compass is a dose computation algorithm which requires modelling of LINAC head similar to other Treatment Planning Systems (TPS). The dosimetry system was commissioned after measuring the required beam data. The validation was performed by comparison of treatment plans generated in Monaco TPS against the measurement data. Different types of simple, complex, static and dynamic radiation fields and highly conformal treatment plans of patients were used in this study.
Results: For all field sizes, point doses obtained from Dolphin-Compass dosimetry were in good agreement with the corresponding TPS calculated values in most of the regions, except the penumbra, outside field and at build-up depth. The results of gamma passing rates of measurements by using different Multi-leaf Collimator patterns and Intensity Modulated Radiation Therapy fluence were also found to be in good correlation with the corresponding TPS values.
Conclusions: The commissioning and validation of dosimetry was performed with the help of various fields, MLC patterns and complex treatment plans. The present study also evaluated the efficiency of the 3D dosimetry system for the QA of complex treatment plans.

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1. Background

The advanced techniques of radiation therapy stand in need of an accurate patient-specific Quality Assurance (QA) programme for verifying treatment plans. American Association of Physicists in Medicine-Task Group (AAPM-TG) report-82 recommends verification of Intensity Modulated Radiation Therapy (IMRT) plans before the treatment delivery.[1] Currently, available dosimetry systems for pre-treatment patient-specific QA are ionization chamber, film dosimeter, two-dimensional (2D) array and Electronic Portal Imaging Device (EPID). All of these detectors have been proven beneficial but also limited with some of their drawbacks.[2–6] Treatment plan verification can be performed by an independent dose calculation, direct dose measurement, or a combination of both. Traditionally, point dose measurements were performed by using a small volume ionization chamber and compared with the treatment plan dose. However, a single point dose is insufficient for dose verification of complex dose distribution of IMRT plans. Radiographic film dosimetry was used for 2D dose verification in a single plane with good resolution, but was limited with its readout system. There are number of commercially available 2D array detectors which are capable of recording the measured fluence and analysing the treatment plan immediately after the delivery. The major limitation of the 2D array is their low resolution, and most of them are not able to display the three-dimensional (3D) dose values. EPID is an efficient real time dosimeter which requires minimum set-up time. But it shows energy dependent radiation response and also is not commonly used in 3D dosimetry. For 3D dose verification, 3D dosimetry using gel and a plastic dosimeter has been developed.[7–9] This technique enables a full 3D dose verification, but requires intensive human resource and time.

At present, IMRT is used as a common technique in many treatment modalities, such as Volumetric Modulated Arc Therapy (VMAT), Stereotactic Body Radiotherapy (SBRT) and Stereotactic Radio Surgery (SRS). The highly complex and conformal dose distribution of these modalities demands critical evaluation of doses to the target as well as to various Organs at Risk (OARs), in addition to the evaluation based on gamma index.[10] A study performed by Nelms et al.[11] discussed the lack of correlation between gamma passing rates from 2D array system and OAR dose differences. Hence, an alternate QA technique is required to verify the 3D dose distribution by measuring fluence at various treatment gantry angles. Dolphin-Compass system (IBA Dosimetry, Schwarzenbruck, Germany) is a commercially available dosimetry solution capable of reconstructing 3D doses in Computed Tomography (CT) images of a phantom or patient. The dose calculation can be performed either without or with the help of measurement. The Compass facilitates the comparison of 3D dose distributions and Dose Volume Histograms (DVH) between planned and computed doses.

The dosimetry using Compass software has been reported by several authors.[12–14] These studies were based on Compass-MatriXX 2D array system. The Compass-Dolphin system is a novel 3D dosimetry technique with a transmission detector of increased spatial resolution, improved measurement performance and high set-up efficiency. Thoelking et al.[15] published the characteristics of the new transmission detector and its influence on surface dose, dose at depth and in various IMRT plans. Another study by Nakaguchi et al.[16] evaluated a method for in vivo 3D dose reconstruction in SBRT using the Dolphin detector. This study also validated the capability of the dosimeter of detecting positional errors of Multi-leaf Collimator (MLC) leaves.

2. Aim

In the present study, we aimed to describe the whole process of commissioning and validation of Dolphin-Compass dosimetry as a patient-specific QA device.

The accuracy of beam modelling was tested with the help of various fields, MLC patterns and complex treatment plans. The study was carried out to evaluate the efficiency of above detector system for the pre-treatment QA of treatment plans, which were generated with complex treatment techniques, such as IMRT, VMAT and SBRT.

3. Materials and methods

The measurements were done on Versa-HD (Elekta, Stockholm, Sweden) Linear Accelerator (LINAC) with 6, 10 and 15 MV photon energy radiation beams. The machine is equipped with Agility (Elekta, Stockholm, Sweden) beam shaping treatment head which has 160 leaves with 0.5 cm width at isocentre. The intensity modulated radiation treatments were performed by using 6 MV photon beams. All the treatment plans were generated in Monaco Treatment Planning System (TPS), version 5.11 (Elekta, Stockholm, Sweden). Dose computation engine based on X-ray Voxel Monte Carlo (XVMC) was used for dose calculation with a grid size of 2.5 mm.

3.1. *Dolphin-Compass system*

The Dolphin-Compass system consists of a 2D array detector and a commercially available DVH-based evaluation tool for patient-specific QA. Dolphin detector is made up of pixel-segmented ionization chamber, which is an array of 1513 air-vented parallel plate chambers. Active measurement area of the detector is 24 cm × 24 cm. The diameter, height and volume of the individual ionization chamber are 3.2 mm, 2 mm and 0.016 cm, respectively. The spatial resolution of the detector is 5 mm for field size up to 14 cm × 14 cm and 10 mm for outside the 14 cm × 14 cm field. The Dolphin detector is mounted on the treatment head of LINAC, and is also capable of measuring the dose online with the patient treatment. The Compass system is a software solution based on collapsed cone convolution/super position dose computation algorithm[17] which required modelling of LINAC head similar to any other TPS. It provides both model-based dose computation and measurement-based dose reconstruction in 3D anatomical volume. For the latter part, a measuring device form IBA dosimetry is required which can be either MatriXX-2D array or more advanced Dolphin detector. The combination of Dolphin and Compass is used in this study. Treatment plans generated by using Monaco TPS were compared with the dose computed by Compass and also with the dose reconstructed after measurement using Dolphin detector.

3.2. *Commissioning and validation of dosimetry*

The Compass software was installed and the dosimetry system was modelled. To commission the beam model, specifications of LINAC and MLC, details of the detector used for measurement and a set of measured beam data were required. The measured data consisted of Percentage Depth Dose (PDD) curves, Crossline (X-axis) and Inline (Y-axis) radiation beam profiles, output factors and absolute output of the LINAC. Measurements were performed in a water phantom, BluePhantom2, radiation field analyser (IBA Dosimetry, Schwarzenbruck, Germany) by using an ionization chamber (CC13) and a diode detector (Razor diode). All the

Table 1 – List of measurements of depth dose curves and output factors for Compass commissioning.

Type of meas.	Field size at SAD (cm × cm)	Depth of meas. (cm)	Detector used for meas.
Depth dose curves	2 × 2	−0.5 to 35	Razor diode
	3 × 3		
	5 × 5		
	10 × 10		CC13-ionization chamber
	15 × 15		
	20 × 20		
	30 × 30		
	40 × 40		
Output factors	2 × 2	10	Razor diode
	3 × 3		
	5 × 5		
	10 × 10		CC13-ionization chamber
	15 × 15		
	20 × 20		
	30 × 30		
	40 × 40		

Abbreviations: meas. = measurement.

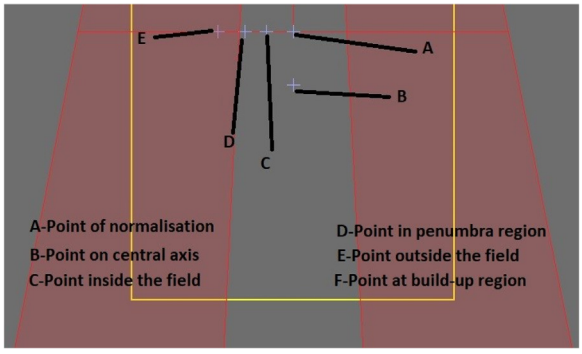

Fig. 1 – Diagram showing various dose points in the phantom.

measurements were done at a fixed Source to Surface Distance (SSD) of 90 cm and for the same set of field sizes. The Field sizes are defined at Source to Axis Distance (SAD) of 100 cm. Tables 1 and 2 show the list of measurements required for commissioning the Compass dosimetry system.

Validation of compass computation algorithm was performed by comparison of treatment plans generated in TPS against the measurement data.

Two different types of radiation fields were used: (1) simple and complex fields prepared in a phantom and (2) IMRT and VMAT treatment fields planned on patient CT data. A homogeneous water phantom of size $30 \times 30 \times 30\,cm^3$ was created in the TPS and open fields of various sizes from $2 \times 2\,cm^2$ to $40 \times 40\,cm^2$ were generated. During the planning, the SSD was 95 cm and a dose of 200 cGy was prescribed at the depth of 5 cm in the phantom. Six user-defined points were created in the phantom, which are described as A, B, C, D, E and F. Position of these points and their descriptions are depicted in Fig. 1.

The doses calculated by TPS at each of these points were compared against the corresponding doses obtained as a result of measurement as well as the computation of Dolphin dosimetry. The dosimetry was also validated in complex segmented intensity modulated radiation fields to capture MLC movement error during the radiation delivery. These static and dynamic fields were prepared with various MLC shapes,

Table 2 – List of measurements of beam profiles for Compass commissioning.

Field size at SAD (cm × cm)	Depth of meas. (cm)	Detector used for meas.
2 × 2	1.6	Razor diode
	5	
	10	
	15	
3 × 3	1.6	Razor diode
	5	
	10	
	15	
5 × 5	1.6	Razor diode
	5	
	10	
	15	
10 × 10	1.6	CC13 ionization chamber
	5	
	10	
	15	
15 × 15	1.6	CC13 ionization chamber
	5	
	10	
	15	
20 × 20	1.6	CC13 ionization chamber
	5	
	10	
	15	
30 × 30	1.6	CC13 ionization chamber
	5	
	10	
	15	
40 × 40	1.6	CC13 ionization chamber
	5	
	10	
	15	

Abbreviation: meas. = measurement.

and include MLC files, such as FOURL, 7SEGA, 3ABUT, HDMLC, HIMRT and DMLC. Clinically approved and verified treatment plans from a group of patients, who completed their treatment by either VMAT or IMRT technique, were also considered for the evaluation. All the above plans were delivered to both Dolphin detector mounted on gantry head and MatriXX 2D array detector in a fixed set-up with a solid water phantom. The reconstructed dose after the fluence measurement by Dolphin and MatriXX 2D array was independently compared against the corresponding TPS generated values.

3.3. *Dosimeter for patient-specific QA*

Compass computes 3D dose by using modelled data of photon beam from LINAC and patient treatment data from TPS. During the process of treatment planning, certain files, such as RTStruct, RTPlan and RTDose, were generated and stored in the Monaco TPS under the respective patient folder. These files along with CT images of the patient were imported into Compass. The RTPlan file is subdivided into a number of control points and each control point is defined with a respective collimator opening and Monitor Units (MU). These parameters along with the commissioned beam data help to calculate the number and energy of photons passing through an area perpendicular to the beam, which is represented as energy fluence. Using this, Compass performs an independent dose computation on CT images without any measurement. A total of 30 cases were considered for this

Table 3 – Comparison of doses of different points for various square fields.

Dose points	Methods	Dose (cGy) for different square fields (cm × cm)									
		2 × 2	3 × 3	4 × 4	6 × 6	8 × 8	10 × 10	15 × 15	20 × 20	25 × 25	30 × 30
Point A	TPS	200.1	200.3	200.1	200.2	199.7	200.2	199.8	199.8	200.9	200.0
	Compass	202.1	200.9	201.1	202.2	200.4	201.2	200.8	201.4	202.8	201.3
	Dolphin	182.2	195.2	196.4	198.4	199.5	199.8	200.3	200.8	201.8	201.7
Point B	TPS	145.8	147.2	148.6	150.7	153.5	155.6	158.4	159.0	160.6	160.8
	Compass	148.4	148.2	149.8	153.0	156.0	158.4	161.0	161.6	163.6	164.1
	Dolphin	133.2	144.1	145.7	153.2	153.7	155.5	158.7	160.7	162.7	163.7
Point C	TPS	177.4	189.5	196.5	200.2	200.0	201.8	202.6	203.5	203.9	205.2
	Compass	177.8	186.7	198.2	202.6	202.6	205.0	205.3	206.1	206.3	207.7
	Dolphin	164.2	183.8	191.4	194.8	196.5	198.0	200.5	201.7	202.9	204.5
Point D	TPS	67.1	75.2	98.8	116.5	144.2	175.6	185.8	164.8	170.7	175.4
	Compass	61.5	69.7	93.6	111.5	141.8	170.6	199.0	166.7	173.5	180.0
	Dolphin	63.2	70.0	93.8	110.2	138.9	167.9	178.9	160.3	166.7	169.8
Point E	TPS	2.3	3.3	4.6	6.9	9.1	10.5	13.4	15.8	20.4	[a]
	Compass	1.5	1.9	3.3	4.7	6.1	6.9	8.9	10.5	22.0	[a]
	Dolphin	4.0	5.1	3.2	7.3	10.9	12.0	15.1	17.2	22.1	[a]
Point F	TPS	242.9	232.5	233.5	229.6	229.2	228.6	230.1	228.5	227.0	225.2
	Compass	244.5	242.2	241.8	238.0	238.6	236.4	234.2	233.6	233.9	233.3
	Dolphin	225.5	230.5	235.5	232.9	233.6	233.3	233.5	232.8	233.0	232.6

[a] No dose calculation is possible at these points.

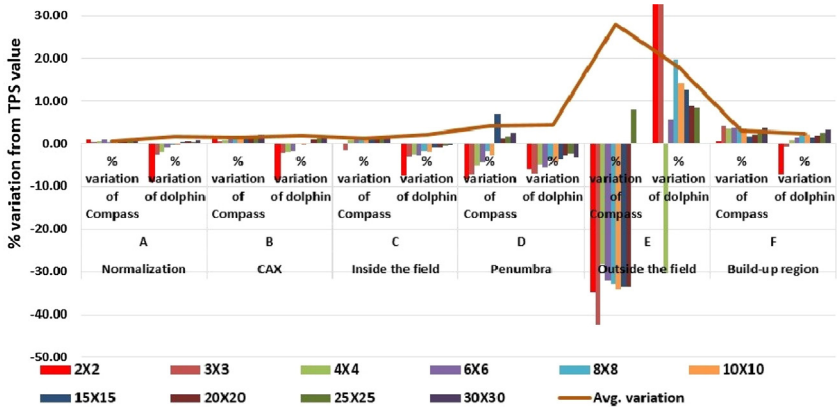

Fig. 2 – Percentage variation in doses of various points in phantom.

study, which included patients with carcinoma of the lung, liver and Head & Neck (HN). These patients had already completed their treatments with different treatment techniques such as IMRT, SBRT and VMAT. The highest dose prescription of SBRT cases was 5500 cGy in 5 fractions. Lung cases were treated with a total dose of 6000 cGy (200 cGy/fraction) and the HN patients were prescribed for a total dose of 7000 cGy (212.1 cGy/fraction). Treatment plans were generated with seven or nine static beam angles for IMRT. The SBRT and VMAT plans had maximum of four full/partial arcs. TPS generated plans were imported, re-calculated with the model based compass dose calculation algorithm. This Compass computed plans were compared and verified with the TPS plans.

The deliverability of treatment plans was verified with the help of measurement-based dose reconstruction of Dolphin-Compass system. Compass predicts a response in the detector measurement plane based on input TPS-fluence, LINAC model and Monte Carlo (MC) derived high resolution detector response model.[18] However, this prediction may not be so accurate due to small errors in the delivery of plans. A measurement based correction factor is applied to the predicted response so that the residual differences between predicted and measured response will be minimized. Once a treatment plan is imported into Compass, it identifies the nominal fluence from Dicom RTplan and a response is predicted with the Compass beam model and the detector response function. The predicted response is compared with the measured response and response difference is divided into two components. The first component is a scaling factor, which is applied to nominal fluence to obtain weighted fluence and the second element is a residual response, which is converted into residual fluence with the help of a deconvolution kernel. The reconstructed fluence is obtained by adding residual fluence and weighted fluence. Thus, the measured response from the Dolphin detector array is converted into delivered fluence with the help of a MC generated ion chamber correction kernel and residual response function. TPS-generated treatment plans were compared, evaluated, and verified against the measurement based dose reconstruction in patient CT images.

The visual comparison of reconstructed and measured dose values was executed by viewing the 2D and 3D dose distributions on CT images. The quantitative 3D evaluation in terms of gamma index was performed for the delivered and Compass computed fluence against the TPS-calculated fluence. The percentage volume of patient and planning target

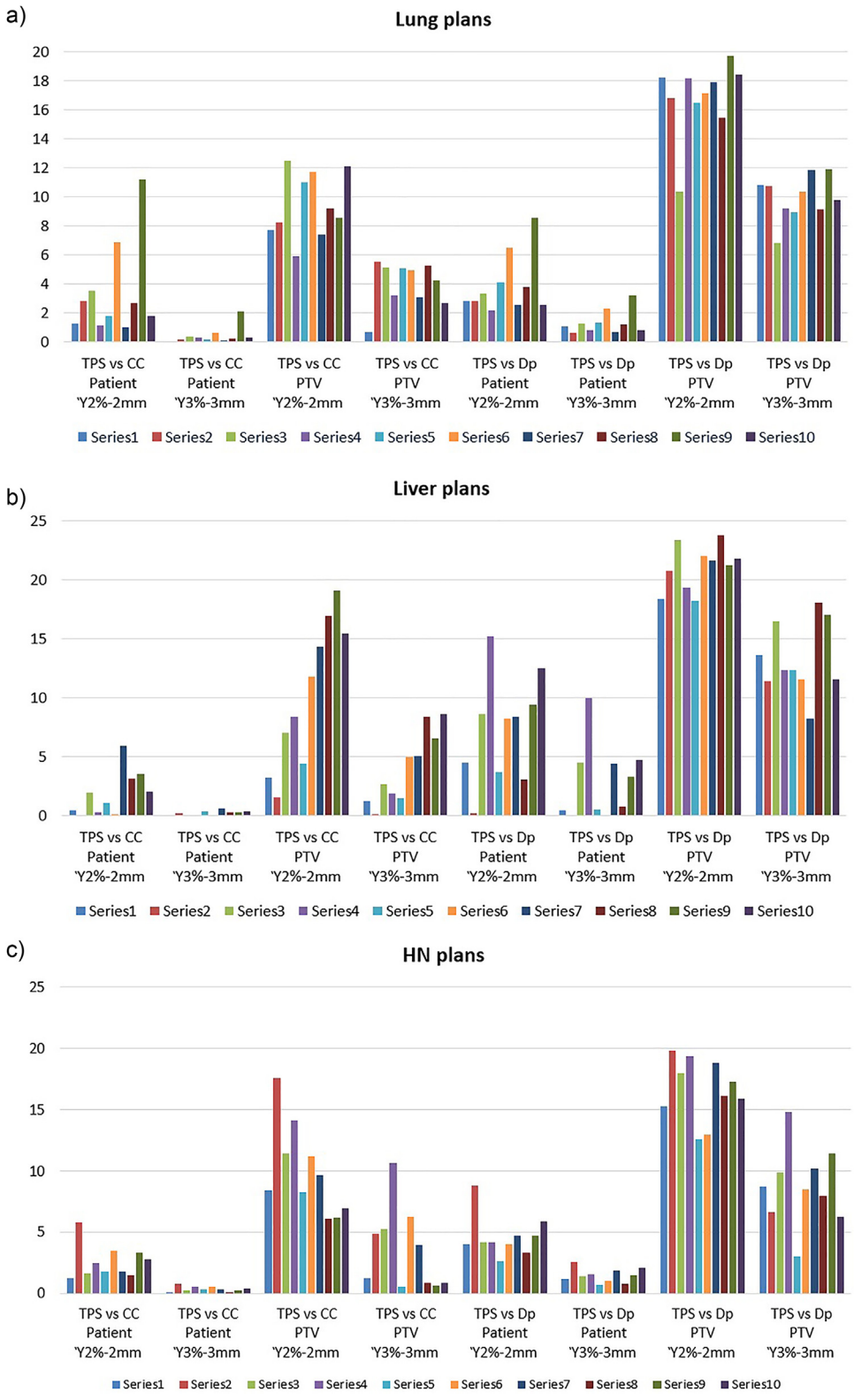

Fig. 3 – Percentage of gamma failing points in patient-specific QA.

on CT with a gamma value less than one ($\gamma < 1$) was obtained and analyzed. The standard passing criterion of 3% – 3 mm (3% for dose difference and the 3 mm for Distance to Agreement (DTA) analysis) and a tighter criterion of 2% – 2 mm were evaluated in this study.

DVH data was compared for evaluating the doses to Planning Target Volume (PTV) and OAR. The near-maximum dose (*D*2%) and the dose to 95% of the volume (*D*95%) were calculated for PTV, whereas the maximum dose (*Dmax*) or mean dose (*Dmean*)/dose to different volumes were studied for OARs.

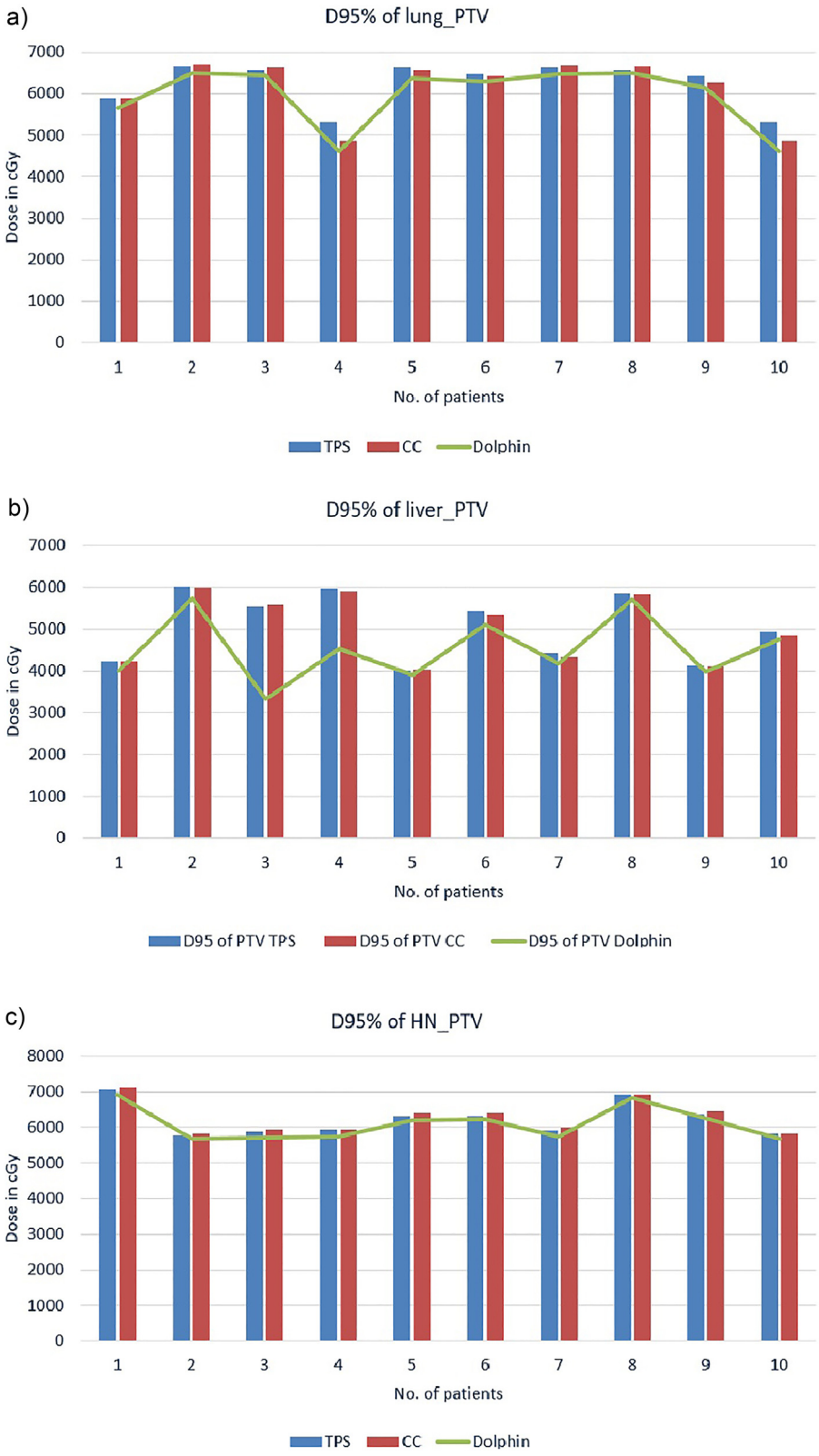

Fig. 4 – Comparison of D95% of PTV between TPS, Compass and Dolphin generated data.

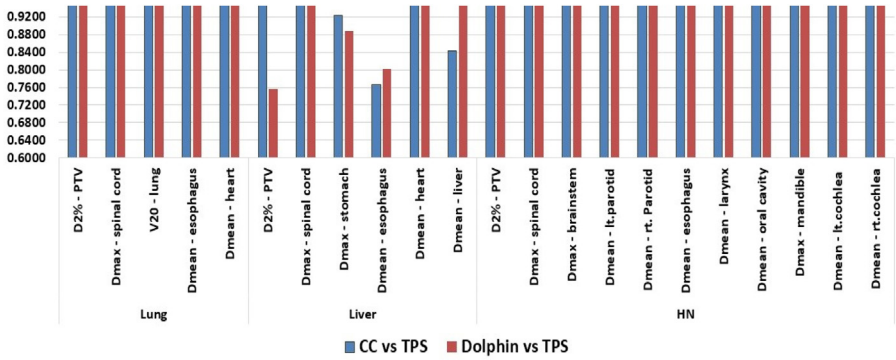

Fig. 5 – Correlation of OAR doses between three systems.

4. Results

4.1. *Validation of Dolphin dosimetry*

Measurements were performed as per Tables 1 and 2 and the data were used for commissioning of Dolphin-Compass dosimetry. As the first step of the validation of dosimetry, the point doses between TPS calculated, Compass computed and Dolphin measured were compared. Table 3 represents the point doses at various locations for different square shaped fields of sizes from $2 \times 2\,cm^2$ to $30 \times 30\,cm^2$. For all field sizes, compass computed doses of points were in good agreement with the corresponding TPS calculated values except in certain regions, such as the penumbra, outside the field and at build-up depth. The comparison of dolphin measured against TPS calculated doses also showed similar behaviour. The average percentage variations of point doses between compass computation and TPS calculation were 4.2 ± 4.9, 9.7 ± 6.5 and 3.0 ± 1.1 for points in the penumbra, out of field and build-up region, respectively. In the case of comparison between dolphin measurement and TPS calculation, the corresponding figures were 4.3 ± 1.5, 0.2 ± 0.2 and 2.4 ± 3.0. The percentage variations of all dose points across various fields are plotted in Fig. 2. The results of gamma passing rate of the TPS calculated complex segmented radiation fields with respect to their compass computed and dolphin measured are summarized in Table 4. The gamma passing rate of square fields and five numbers of patient plans are also shown in Table 4. The TPS calculated fluences were also compared with those measured by using another array detector, MatriXX 2D ionization chamber array. This array detector can directly calculate dose from measurements without the need to remodel the beam.

4.2. *Patient-specific QA*

The results of patient-specific QA in terms of percentage of gamma failing are depicted in Fig. 3. The measured and compass computed plans were compared with respect to their TPS plans for three different treatment sites. In the case of lung plans, the percentage of failed points in standard gamma criterion (3% – 3 mm) is 0.43 ± 0.6 and 3.94 ± 1.6 in patient and planning target volume, respectively, when comparing the compass computed and TPS calculated fluence. The corresponding values are 1.33 ± 0.8 and 9.95 ± 1.5 during the comparison of measured and TPS fluence. Similarly, the percentage of gamma failing points is 0.23 ± 0.2, 4.11 ± 3.1, 2.88 ± 3.2 and 13.26 ± 3.1 for liver plans and 0.38 ± 0.2, 3.54 ± 3.3, 1.49 ± 0.6 and 8.75 ± 3.2 for HN plans. Gamma failing points calculated by using stricter gamma criterion (2% – 2 mm) were also evaluated and these values showed similar behaviour in different cases. In all these cases, measured plans showed relatively larger number of failure points in PTV in comparison with patient volume.

Table 4 – Comparison of gamma passing values of complex segmented MLC fields, square fields and patient-specific QA plans.

Radiation fields	% of points passing the γ Compass vs TPS	(3 mm – 3%) criterion Dolphin vs TPS
FOURL	100	99.2
7SEGA	99.5	97.5
3ABUT	99.5	96.6
HDMLC	100	100.0
HIMRT	100	99.6
DMLC	100	99.2
$2 \times 2\,cm^2$	100	99.5
$3 \times 3\,cm^2$	100	99.0
$4 \times 4\,cm^2$	100	99.3
$6 \times 6\,cm^2$	100	99.5
$8 \times 8\,cm^2$	100	99.8
$10 \times 10\,cm^2$	99.8	99.7
$15 \times 15\,cm^2$	100	99.5
$20 \times 20\,cm^2$	100	99.3
Patient 1	97.8	96.7
Patient 2	98.2	95.4
Patient 3	96.5	94.5
Patient 4	98.0	98.7
Patient 5	99.8	99.2

Target coverage was estimated in terms of *D*95% and maximum dose was obtained as *D*2% for the PTV. The DVH comparison data of *D*95% of the PTV between Compass-computed, Dolphin-measured and TPS-calculated are shown in Fig. 4. The *Dmax*, *Dmean* and volume dose for various OARs were also studied and the correlation of these data between three systems are plotted in Fig. 5.

5. Discussion

In the present study, we extensively described the commissioning and validation of Dolphin-Compass dosimetry and the patient-specific QA by using this dosimetry. Unlike other 2D dosimetry for IMRT QA, Compass required a beam modelling for its commissioning. It is necessary to measure the required beam data accurately to ensure the correct beam modelling of Compass. Fig. 6 represents the (a) PDD of 6 MV beam for different field sizes, (b) and (c) crossline and inline

profiles for selective field sizes at four different depths of 1.6 cm, 5.0 cm, 10.0 cm and 20.0 cm. Output factors of the beam are shown in Table 5. All the above data are in good agreement with the baseline values, measured at the time of commissioning of LINAC. The method of validation of new dosimetry involved measurement of uniform and non-uniform fluences obtained from different square shaped fields and from static or dynamic MLC patterns. The agreement in

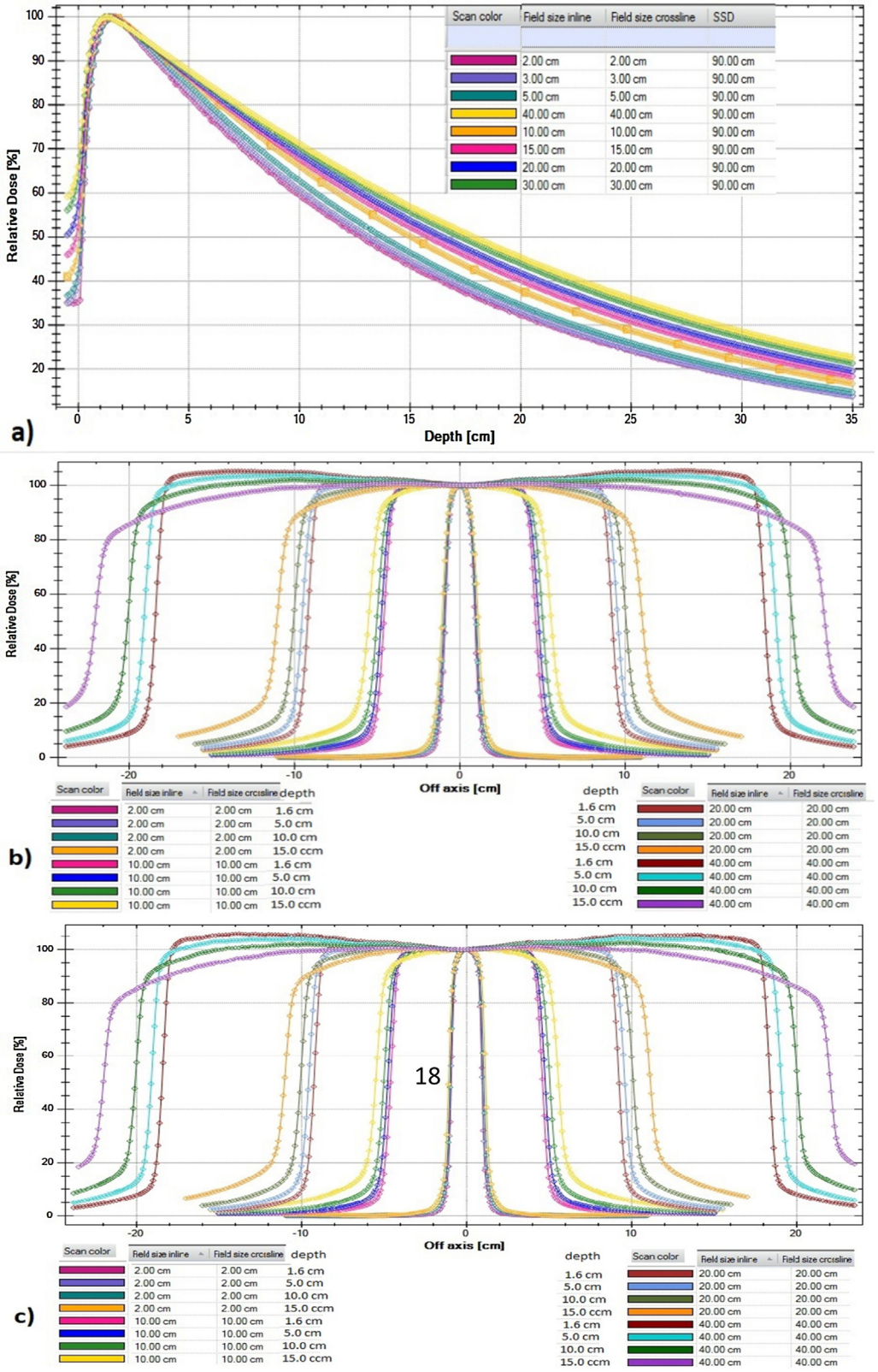

Fig. 6 – Beam data measurements: (a) PDD for different field sizes, (b) crossline beam profile for selective fields and (c) inline beam profile for selective fields.

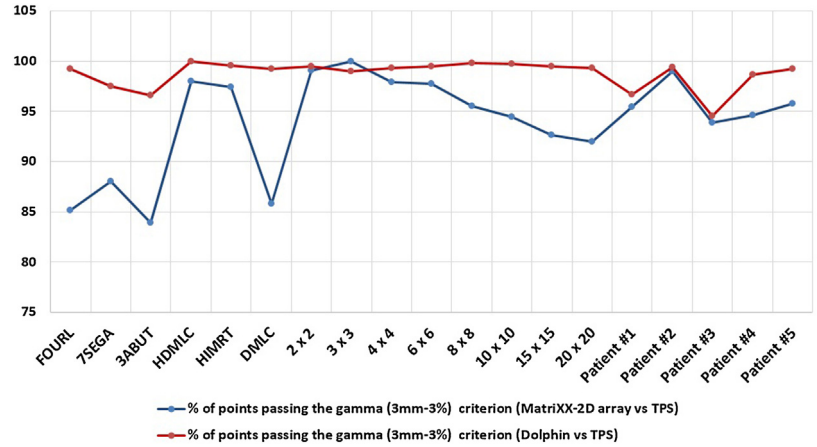

Fig. 7 – Results of gamma comparison between Dolphin and Matrixx 2D array.

Table 5 – Output factors of 6 MV beam for various field sizes.

Field size at SAD (cm × cm)	Output factor
2 × 2	0.789
3 × 3	0.846
5 × 5	0.906
10 × 10	1.000
15 × 15	1.056
20 × 20	1.092
30 × 30	1.136
40 × 40	1.153

point doses at various locations in and around the square fields verified the accuracy of Dolphin-Compass dosimetry. However, the disagreement in doses of three different points (D, E and F in Fig. 1) in the phantom showed the limitation of this dosimetry for predicting low intensity, more of scattered component and near-surface dose. Dolphin accurately measured doses inside the field size of $3 \times 3\,cm^2$ and above. In the case of extremely small field ($2 \times 2\,cm^2$), the observed variation was −8.9%, −8.6% and −7.4% for points A, B and C (Fig. 1), respectively, which appeared to be due to the limitation of small-field dosimetry. The measurements by using different MLC patterns and complex IMRT fluence also revealed the efficiency of Dolphin dosimetry for IMRT verification. Moreover, we were able to confirm the accuracy of the Dolphin dosimetry by using MatriXX 2D ionization chamber detector. The comparison data are depicted in Fig. 7. The results obtained from MatriXX 2D array are found to be closer to those from Dolphin detector for square fields and IMRT plans. The average differences of gamma (3% – 3 mm) values were 3.27% and 1.94% for these fields and the maximum variation was observed for MLC patterns such as FOURL, 3ABUT and DMLC, as is evident from Fig. 7. More failure points are observed at the edges of these complex intensity fields. This caused the MatriXX-2D array measurement to deviate slightly from the results of Dolphin. Thus, the results of open-field, MLC patterns and patient-specific QA suggested that the dosimetry system could provide adequate accuracy for clinical use and also confirmed that the beam model was set appropriately.

Dolphin-Compass dosimetry is superior to many other QA systems because of its capability of calculating 3D dose on patient CT scan using beam modelling, array detector measurement and treatment plan. We measured a total of 30 treatment plans, which consisted of IMRT, SBRT and VMAT techniques. The TPS plans were compared with corresponding Dolphin-measured and the Compass-computed plans. Most of our gamma comparison results are well within the clinically acceptable tolerance level of 5%.[19] The results of 3D comparison show that more than 95% of pixels are passing in both PTV and patient volume within 3% – 3 mm gamma criterion during the comparison of Compass vs. TPS.

In the case of verification by measurement, percentage of pixels in the patient volume is well agreed with the TPS for all studied plans. However, there are a few failure points in PTVs of lung, liver and HN plans. Out of these, liver plans showed more failure (13.26 ± 3.1) points in gamma values, which is due to the higher complexity and conformity of SBRT plans. The higher deviation of fluence over very small distances results in a failure in gamma, which is due to the reconstruction inaccuracies of Compass and limited resolution of Dolphin. However, SBRT requires a QA tool with the least dependency on high dose and dose rate.[16] The Dolphin detector consists of an ionization chamber, which is the least dependent on the above factors. Another important aspect of this study is the 3D dose comparison with the help of DVH. By using collapsed cone convolution/super position algorithm, Compass performs an independent dose computation and also reconstructs the 3D dose distribution from measured fluence. The TPS calculated *D*95% of the PTV is found to be correlated with the measured as well as the reconstructed values. Also, the TPS calculated various OAR dose values are in good agreement with the other two systems. As it is evident from Fig. 5, the maximum variations of OAR dose values are within 1.0% for lung and HN cases, whereas certain OAR of SBRT cases show relatively larger disagreement between measured, Compass-computed and TPS-calculated values.

The Dolphin-Compass dosimetry fails to reproduce a steeper dose-fall because of the stringent dose volume criteria used in SBRT treatment planning. The overall results of the patient specific QA from three different complex sites are satisfactory.

For 3D dosimetry, a few other techniques such as a film, EPID and LINAC log file based dose reconstructions are also available now. The major drawback of fluence reconstruction by using a film is the large time requirement for the measurement and analysis. Also, this relative dosimetry method cannot provide information during the course of irradiation. However, a 2D detector array is able to measure fluence during the delivery causing the analysis of the results to be easier and, hence, it is simple to integrate a clinical practice. EPID dosimetry is comparable with this, but neither is its implementation easier nor does it offer an energy dependent response. Reconstruction based on log file is not an independent dosimetry

check and it always shows delay in analysis. The 3D dosimetry using Dolphin detector is an emerging solution in patient-specific QA. Ionization chamber array always raises concern of limited resolution. However, the Dolphin-Compass system can detect small changes of dose profiles and DVH in comparison to other 2D array detectors. This is because the system is based on a reconstruction method by combining sensitive ionization chambers and accurate beam modelling.[20] Also, the Compass 3D dosimetry uses a sufficiently accurate algorithm for dose determination which is independent from the TPS. Therefore, it can be used for a TPS QA to check the commissioning data and routine dose calculation of TPS. Three dimensional DVH analysis along with the conventional 2D gamma passing rates provides extra confidence for assuring the accuracy in delivery of treatment plans. Dolphin is designed for ease of use, can be made available for measurement within 2 min by simply attaching to the gantry and is operated wirelessly. This dosimetry offers instant verification and confirmation of each delivered beam segments and is able to display the results automatically.

6. Conclusion

Traditional patient-specific QA methods are performed in a phantom and it is not possible to quantify the QA results in patient anatomy. The capability of Dolphin-Compass dosimetry to reconstruct the 3D dose on patient CT was studied in detail. The dosimetry system was installed by using modelled beam data of LINAC head. The accuracy of beam modelling was validated and a comprehensive 3D dose comparison was performed. The efficiency of the detector system for the patient-specific QA of complex treatment plans using modern techniques, such as IMRT, VMAT and SBRT, were investigated.

Conflict of interest

None declared.

Financial disclosure

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