DIFFERENCE BETWEEN RADIOTHERAPY QUALITY ASSURANCE DEVICES (ARC- AND MAP-CHECKS)

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The radiotherapy is a complex procedure and involves understanding of the principles of medical physics, radiobiology, radiation safety, dosimetry, radiation treatment planning, simulation and interaction of radiation with other treatment modalities. Each step in the integrated process of RT needs quality control and quality assurance to prevent errors and to give high confidence that patients will receive the prescribed treatment correctly. A patient-specific quality assurance program has been developed to facilitate the clinical implementation of the intensity-modulated radiotherapy delivered using a micro-multileaf collimator. The methodology includes several dosimetric tasks that are performed prior to the treatment of each patient. Film dosimeter is performed for each individual field and the multifield composite plan. Individual field measurements are performed at a depth of 5 cm in a water equivalent slab phantom. The heterogeneity inserts of phantom are 2 cm×2 cm×22 cm with absorption characteristics of water, brain, muscle, lung, breast, adipose tissue, bone, and liver.

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INTRODUCTION

The purpose of the research is related to the need to develop an analytical approach to planning and question anything different from the norm. This study was conducted to verify planar dose distributions acquired during the pretreatment step of the radiotherapy (RT), in particular, the patient-specific intensity-modulated-radiotherapy (IMRT) quality assurance (QA) delivered at LIV Hospital Radiation Medicine Centre (Tbilisi, Georgia).

EXPERIMENTALS

Our study took one year to provide the appropriate radiation database with clinical conditions: ELEKTA, type of treatment machine, and treatment planning systems (TPS); Treatment approaches: IMRT, S and S IMRT, SBRT, SRS, and volumetric-modulated-arc-therapy (VMAT); QA-devices: Subnuclear, Arc-Check, and Map-Check; Fraction dose: between 1.5–3.0 Gy; and the number of patients: breast – 87 and larynx – 504.

RESULTS AND DISCUSSION

Five hundred ninety-one patient data were evaluated for a time ranging from 2017 to 2018. These data were gauged using several methods used in the QA process. Several patient plan QA in the latter years.

Patients were grouped according to several parameters including TPS, site of treatment, and type of treatment machine used in comparing the measured versus computed dose differences.

With the introduction of advanced RT techniques such as VMAT and IMRT, the three-dimensional (3D) dose distribution for radiation therapy has become both more conformal and complex. These features pose a great challenge for the QA of the dose distribution, which commonly consists of both point dose and two-dimensional (2D) plane dose measurements.[1] And an urgent need for 3D dosimetry has also been stated.[2]

Various techniques have been developed to compare measured dose distributions with those generated by the treatment planning system.[3–24] The *c*-index technique,[3,4] which is the standard method for planar dose verification in IMRT QA,[5,6] calculates the quantity *c* for each point of interest using preselected dose-difference (DD) and distance-to-agreement (DTA) criteria and then uses the *c* value to determine the outcome (pass–fail) of the IMRT QA.

QA measurements are conducted per year for each patient. Quality assurance is specifically defined as the systematic actions necessary to ensure that a product or process performs to specification. The accuracy of each step in the process has a direct impact on treatment outcome.

The following criteria are used for absolute dose and relative dose to determine if a point passes or fails: threshold (TH %), percent difference (Diff %), and distance (Dist, mm). TH % is the minimum dose percent value that must be met in either the device measured or planned dose data for the point to be included in the analysis. Global, so-called Van Dyk, Diff % is the percent difference between the doses at any measured point and the corresponding plan point normalized to a common point (a user-selected normalization point or the maximum dose point – default).

As for the Dist, it is a radius in mm around the measured point. This test refers to points, where the difference between measured and planned values of co-located points exceeds the selected percent difference. Using the distance to agreement criteria, measured point passes if, within a circle of DTA in mm, there exists at least one plan point that is greater than or equal to and at least one plan point that is less than or equal to the value of the measured point. The plot (Table 1) shows all the measurement points that are not in agreement. The points that record a higher value are shown in red (hot) while those that record a lower value are shown in blue (cold).

Table 1. Quality assurance data of breast patients.

Treatment approach	PTV1	PTV2	PTV3	Fraction #	QA Device	Machine	AD Local	AD Global
diMRT	12			6	MapCheck2	Synergy	100	100
diMRT	22			11	MapCheck2	Synergy	95,9	100
diMRT	22			11	MapCheck2	Synergy	98	100
diMRT	69	65	50	37	MapCheck2	Synergy	95,3	99,8
diMRT	14			7	MapCheck2	Synergy	93,8	97,5
diMRT	70	60	54	39	MapCheck2	Synergy	93	100
diMRT	25			9	MapCheck2	Synergy	96,4	99,7
diMRT	27,8	27,8		35	MapCheck2	Synergy	94,6	99,6
diMRT	46			23	MapCheck2	Synergy	98,8	100
diMRT	70	62	56	39	MapCheck2	Synergy	99	100
diMRT	51	54		35	MapCheck2	Synergy	96,6	99,6
diMRT	70	62	58	45	MapCheck2	Synergy	95,6	99,9
diMRT	70	62	58	35	MapCheck2	Synergy	89,7	99,1
diMRT	64			32	MapCheck2	Synergy	100	100
diMRT	22			13	MapCheck2	Synergy	99,7	99,7
diMRT	18			9	MapCheck2	Synergy	100	100
diMRT	70	58		35	MapCheck2	Synergy	99	100
diMRT	70	58		35	MapCheck2	Synergy	97,3	99,5
diMRT	50			25	MapCheck2	Synergy	99,5	100
diMRT	70	55		61	MapCheck2	Synergy	95,1	98,7
diMRT	50			26	MapCheck2	Synergy	98,5	97
diMRT	60			28	MapCheck2	Synergy	94,1	100
diMRT	56			28	MapCheck2	Synergy	93	97,3
diMRT	33			10	MapCheck2	Synergy	99,5	99,7
diMRT	70	58		35	MapCheck2	Synergy	97,1	99,8
diMRT	51			25	MapCheck2	Synergy	97,4	100
diMRT	62	58	54	31	MapCheck2	Synergy	96,2	100
diMRT	28	24		8	MapCheck2	Synergy	100	100
diMRT	70	55		33	MapCheck2	Synergy	93	99,3
diMRT	69			28	MapCheck2	Synergy	100	100
diMRT	70	62	57	35	MapCheck2	Synergy	97,7	99,5
diMRT	50			25	MapCheck2	Synergy	98,5	100
diMRT	45	40		15	MapCheck2	Synergy	99	100
diMRT	58			28	MapCheck2	Synergy	99,7	100
diMRT	63			28	MapCheck2	Synergy	96,4	96,4
diMRT	30			10	MapCheck2	Synergy	93,9	94,8
diMRT	50			25	MapCheck2	Synergy	95,5	100
diMRT	70	60	56	35	MapCheck2	Synergy	88,9	98,2
diMRT	50			25	MapCheck2	Synergy	96	99,4
diMRT	70	60	50	35	MapCheck2	Synergy		
diMRT	70	63	58	35	MapCheck2	Synergy	89,3	93,4
diMRT	70	63	58	35	MapCheck2	Synergy	89,5	99,1
diMRT	70	63	58	35	MapCheck2	Synergy	95,8	99,2
diMRT	40			5	MapCheck2	Synergy	97,7	97,7
diMRT	62	60	54	31	MapCheck2	Synergy	96	100
diMRT	60	58	54	30	MapCheck2	Synergy	97	100
diMRT	70	56		35	MapCheck2	Synergy	92,1	98,3
diMRT	70	62	56	35	MapCheck2	Synergy	98,7	100

Table 2. Quality assurance data of larynx patients

Treatment approach	PTV1	Fraction #	QA Device	Machine	AD Local	AD Global	RD
VMAT	40	10	ArcCheck	Versa HD	89,5	93,6	91,4
VMAT	70	35	ArcCheck	Versa HD	92,2	99,6	100
VMAT	40	35	ArcCheck	Versa HD	96,5	100	100
VMAT	48	24	ArcCheck	Versa HD	99,2	99,9	100
VMAT	26	13	ArcCheck	Versa HD	99,9	100	100
VMAT	24	12	ArcCheck	Versa HD	99,3	100	100
VMAT	70	35	ArcCheck	Versa HD	96	99,8	99,9
VMAT	70	35	ArcCheck	Versa HD	94	99,6	99,7
VMAT	34	17	ArcCheck	Versa HD	99	99,7	99,9
VMAT	70	35	ArcCheck	Versa HD	94,9	99,6	99,9
VMAT	60	30	ArcCheck	Versa HD	80	96,8	97,8
VMAT	32	16	ArcCheck	Versa HD	92,2	97,8	97,4
VMAT	70	35	ArcCheck	Versa HD	97,8	100	100
VMAT	60	28	ArcCheck	Versa HD	98,9	100	100
VMAT	70	34	ArcCheck	Versa HD	91	98,8	99,6
VMAT	70	35	ArcCheck	Versa HD	97,3	99,9	99,9
VMAT	45	25	ArcCheck	Versa HD	97,7	99,8	99,9
VMAT	50	28	ArcCheck	Versa HD	85,3	94,6	97,4
VMAT	60	28	ArcCheck	Versa HD	98,7	100	100
VMAT	60	30	ArcCheck	Versa HD	79	95,4	99,8
VMAT	60	30	ArcCheck	Versa HD	87,7	95,8	98,6
VMAT	42	21	ArcCheck	Versa HD	85,1	96,5	99,2
VMAT	63	28	ArcCheck	Versa HD	92,7	99,6	99,7
VMAT	70	35	ArcCheck	Versa HD	97	100	100
VMAT	50	28	ArcCheck	Versa HD	93,3	98	97,8
VMAT	36	20	ArcCheck	Versa HD	95,1	99,7	99,7
VMAT	18	9	ArcCheck	Versa HD	78,8	92,8	97,4
VMAT	45	15	ArcCheck	Versa HD	93,7	99,3	98,8
VMAT	60	31	ArcCheck	Versa HD	95	98,2	98,6
VMAT	70	35	ArcCheck	Versa HD	96,1	99,6	99,6
VMAT	30	10	ArcCheck	Versa HD	100	100	100
VMAT	30	10	ArcCheck	Versa HD	85,8	94,1	99,4
VMAT	70	35	ArcCheck	Versa HD	90	96,6	
VMAT	70	35	ArcCheck	Versa HD	95,6	99,1	98,8
VMAT	70	35	ArcCheck	Versa HD	97,3	99,8	99,6
VMAT	66	33	ArcCheck	Versa HD	86,1	97,8	97,5
VMAT	70	35	ArcCheck	Versa HD	90,7	95,3	96
VMAT	34	17	ArcCheck	Versa HD	93,9	98	99,1
VMAT	63	28	ArcCheck	Versa HD	89,7	96	95,2
VMAT	62	31	ArcCheck	Versa HD	91,4	99,2	99,4
VMAT	60	30	ArcCheck	Versa HD	93,4	99,4	99,2
VMAT	60	30	ArcCheck	Versa HD	96,2	99,6	99,6
VMAT	70	35	ArcCheck	Versa HD	94,1	98,1	100
VMAT	64	32	ArcCheck	Versa HD	85,6	95,6	99,2
VMAT	30	17	ArcCheck	Versa HD	89,4	95,6	97,7
VMAT	50	25	ArcCheck	Versa HD	94,3	97,1	99,2
VMAT	50	25	ArcCheck	Versa HD	100	100	100
VMAT	70	35	ArcCheck	Versa HD	94,5	99,2	99,3
VMAT	60	30	ArcCheck	Versa HD	70,9	80,4	92,6
VMAT	60	30	ArcCheck	Versa HD	69,4	80,2	92

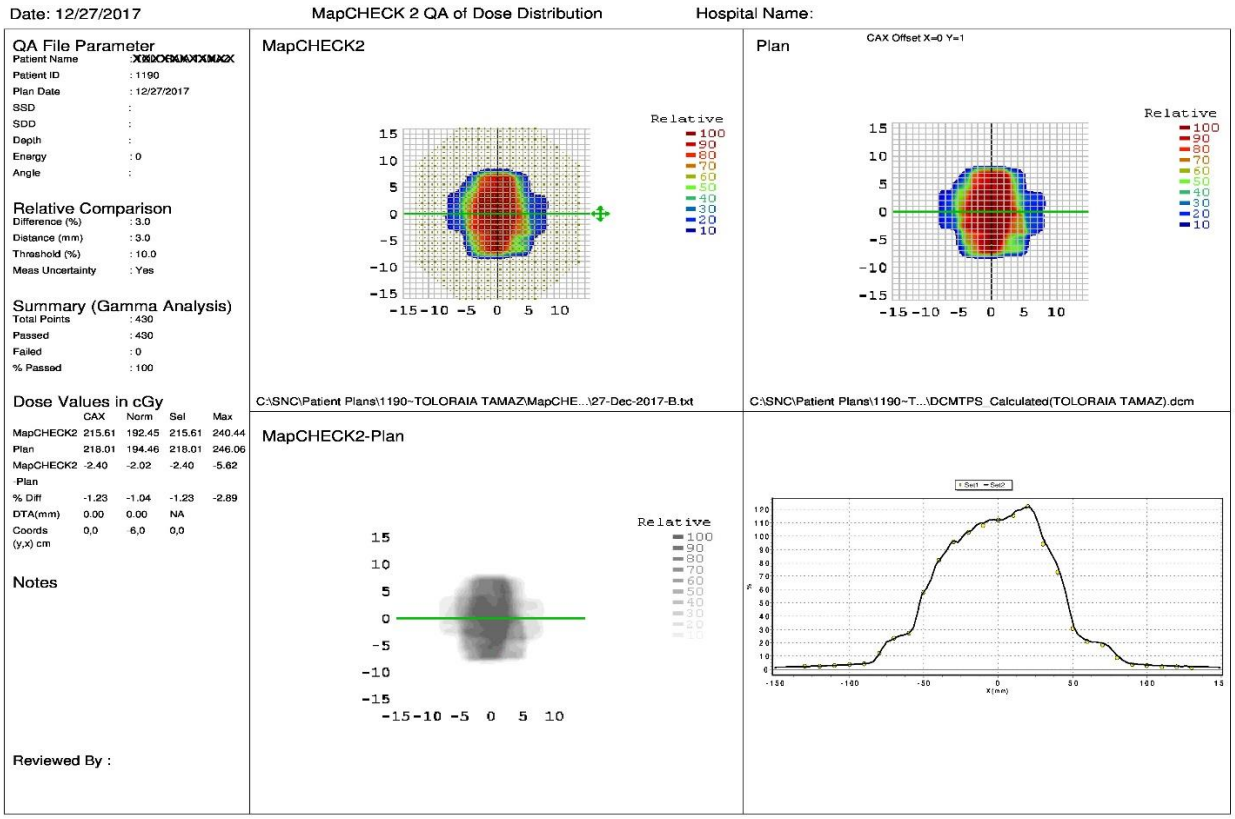

Figure 1. Dose distribution - larynx patient

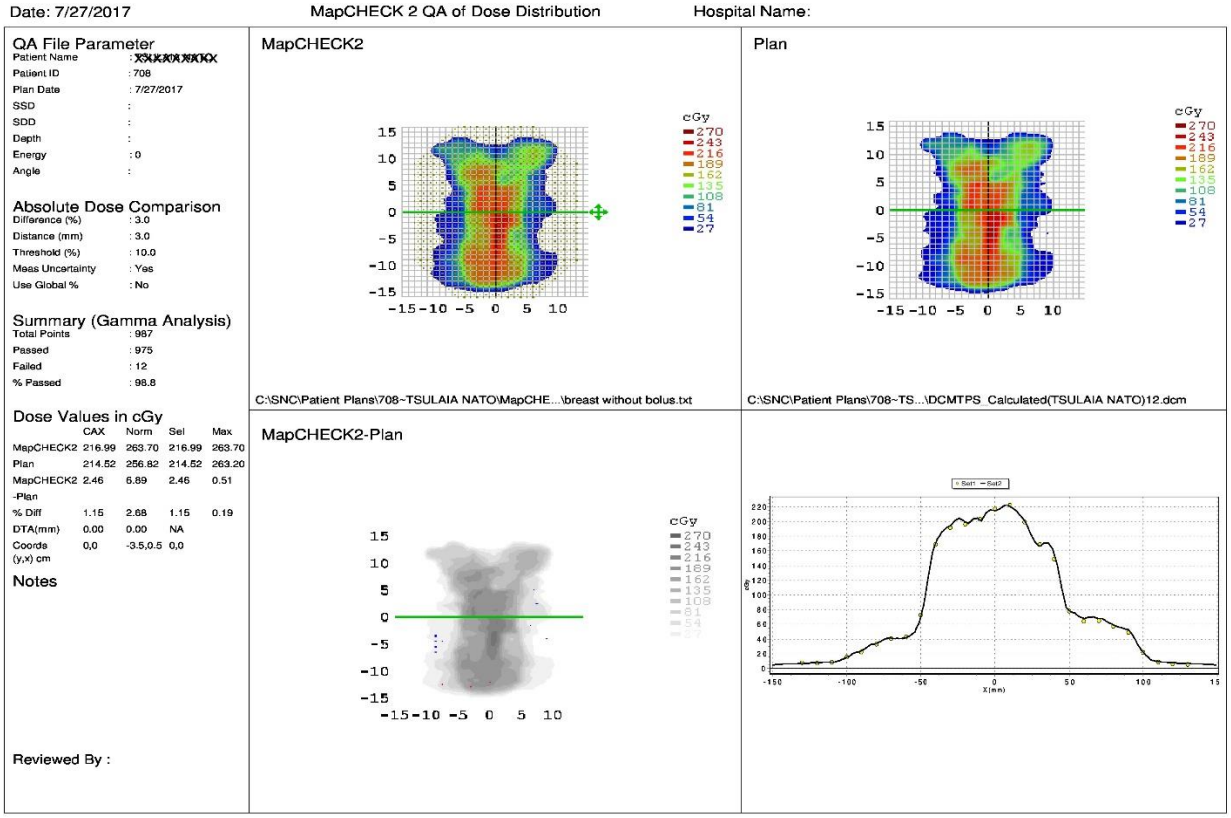

Figure 2. Dose distribution - breast patient

If the Global % checkbox is selected in the analysis panel, the Van Dyk comparison is used during DTA and gamma analysis (Figures 1 and 2).

Global % difference for DTA analysis is defined as the following expression in the SNC patient software:

$$PDE_{k,l} = 100\frac{M_{g,h} - P_{k,l}}{P_{norm}}$$

where:

$PDE_{k,l}$ is the percent dose difference between $M_{g,h}$ and $P_{k,l}$,

$M_{g,h}$ is the measured value at the point (g, h),

$P_{k,l}$ is the planned value at the point (k, l), and

P_{norm} is the planned value at the normalization point.

Global % difference for gamma analysis is defined as the following expression in the SNC patient software:

$$PDE_{k,l} = 100\frac{P_{k,l} - M_{g,h}}{M_{norm}}$$

where:

$PDE_{k,l}$ is the percent dose difference between $M_{g,h}$ and $P_{k,l}$,

$M_{g,h}$ is the measured value at the point (g, h),

$P_{k,l}$ is the planned value at the point (k, l), and

M_{norm} is the measured value at the normalization point.

CONCLUSION

For dose distribution overlays or dose-difference determinations, the results were independent to within a sign of selection of the reference or evaluated distribution. However, for the DTA and γ tools, the results could be profoundly affected by the selection, especially when one or both of the dose distributions contained some noises. Typically, the reference and evaluated distributions would refer to measured and calculated distributions, respectively. But, the final selection should be based on which distribution is considered the standard by which the other is compared.

The γ tool provides a quantitative method for comparing two dose distributions. In this paper, we have shown the utility of the tool to compare two similar dose distributions and evaluated the sensitivity of the tool to pseudorandom noise. In all of these tests, the dose and distance criteria were fixed, preselected values. In practice, the values can be set as functions of space the location of the dose comparison or dose value.

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