ArcCHECK for machine and patient specific QA: Which digital phantom should be used?

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INTRODUCTION

Unity is the first high field MR-linac. The dose distribution, especially at the interface of nonuniform media is much different compared with conventional linac because of the presence of magnetic field.

ArcCHECK has been used for machine and patient specific QA for conventional linac for many years. The planned doses were usually calculated with one of two digital phantoms of ArcCHECK, virtual phantom with the uniform relative electron density (RED) of 1.15[4], provided by manufacturer (VP_m)[3, 4, 6, 9] and image dataset scanned by MVCT (MP)[1, 8]. The performances and feasibility of ArcCHECK QA system with both digital phantoms have been evaluated and confirmed[1-8]. The virtual phantom of ArcCHECK-MR, the MR compatible version of ArcCHECK, was recommended to use for machine and patient specific QA for MR-linac. However, in the commissioning of the ArcCHECK-MR, the RED was recommended to be adjusted to maximize the agreement (gamma pass rate) between the measured and planned doses[13,15].

Whether MP can be used for MR-linac and the most suitable phantom for machine and patient specific QA with and without magnetic field were still unclear.

AIM

To determine which digital phantom of ArcCHECK should be used for linac with and without magnetic field.

METHOD

Three digital phantoms

A MVCT-RED table was established by matching the MVCT value of each plug-in on MVCT image of Cheese phantom and its RED. The MVCT image of ArcCHECK-MR was imported into TPS and saved as MP. Virtual phantoms with uniform RED of 1.15 recommended by manufacturer, and 1.125 after achieving maximum agreement between measured and planned doses, was saved as VP_m and VP_{ad}.

Planned dose

15 simple plans with various field sizes and 14 treatment plans for patients were designed using IMRT technique for both Versa HD and Unity, because they have similar treatment head. Planned doses were calculated with MP using MVCT-RED table, and VP_m, as well as VP_{ad} using specific uniform RED respectively.

Measured dose

Before the measurement, the QA for both Unity and Versa HD were carefully performed. The position accuracy of ArcCHECK-MR was verified by EPID. The measured doses were acquired after careful background correction and absolute and relative dose calibrations.

Date analysis

γ-analysis were performed on each pair of measured and planned doses with criteria of 2mm/3% and 2mm/2% for patient and simple plans, respectively, using a 10% global threshold. The differences in γ pass rates (GPR) were statistically analyzed using paired t test.

RESULTS

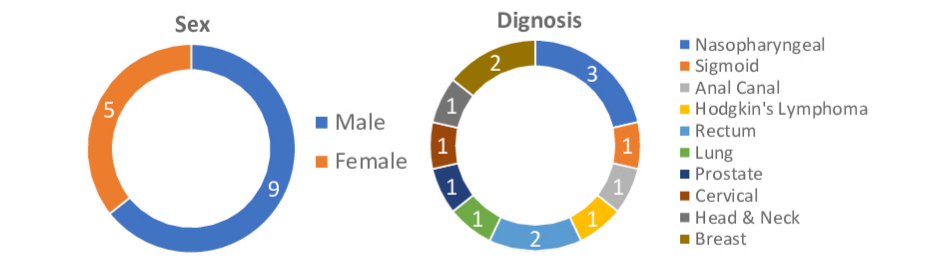

Figure 1. Summary of patient characteristics

Table 1. Gamma pass rates for ArcCHECK-MR measurements of simple plan and patient plan

Linac	Plan	Phantom	GPR	*P*	
Unity	Simple Plan	MP	91.49%±6.88%	VP_m vs. VP_{ad}	0.183
		VP_m	85.72%±10.23%	MP vs. VP_m	0.003
		VP_{ad}	87.29%±9.24%	MP vs. VP_{ad}	0.009
Versa HD		MP	89.55%±10.04%	VP_m vs. VP_{ad}	0.242
		VP_m	90.39%±8.82%	MP vs. VP_m	0.416
		VP_{ad}	90.81%±8.43%	MP vs. VP_{ad}	0.218
Unity	Patient Plan	MP	96.20%±2.61%	VP_m vs. VP_{ad}	0.013
		VP_m	93.81%±4.00%	MP vs. VP_m	0.024
		VP_{ad}	94.95%±3.32%	MP vs. VP_{ad}	0.142
Versa HD		MP	91.61%±5.46%	VP_m vs. VP_{ad}	0.001
		VP_m	89.92%±5.42%	MP vs. VP_m	0.059
		VP_{ad}	91.65%±5.12%	MP vs. VP_{ad}	0.947

For both Versa HD and Unity, a higher GPR can be achieved by adjusting the RED of ArcCHECK-MR image, an increase in the average GPRs can be observed compared with those with VP_m, although it is insignificant for simple plan but significant for patient plan.

For Versa HD, The differences of GPR among the three digital phantoms are minor (all Ps>0.05) for simple plan. The GPRs with MP are higher than those with VP_m for patient plan, but the difference is insignificant (p=0.059).

For Unity, the highest GPRs are achieved with MP for both simple plan (91.49%) and patient plan (96.20%). The differences are significant for simple plan (p=0.003 and 0.009 for VP_m and VP_{ad}, respectively), as well as the patient plan calculated with VP_m(p=0.024) .

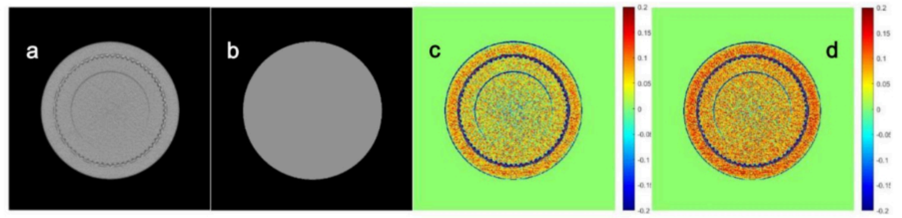

Figure 2. RED of (a) MP and (b) VP, and (c) the difference between MP and VP_m, (d) the difference between MP and VP_{ad}.

It is noted that the RED inside the MP phantom is nonuniform. There are obvious air gaps at the detector layer and the interface of plug-in.

The RED difference would increase if the RED of virtual phantom is changed from 1.15 to 1.125. It is unreasonable to change the RED to improve the GPS.

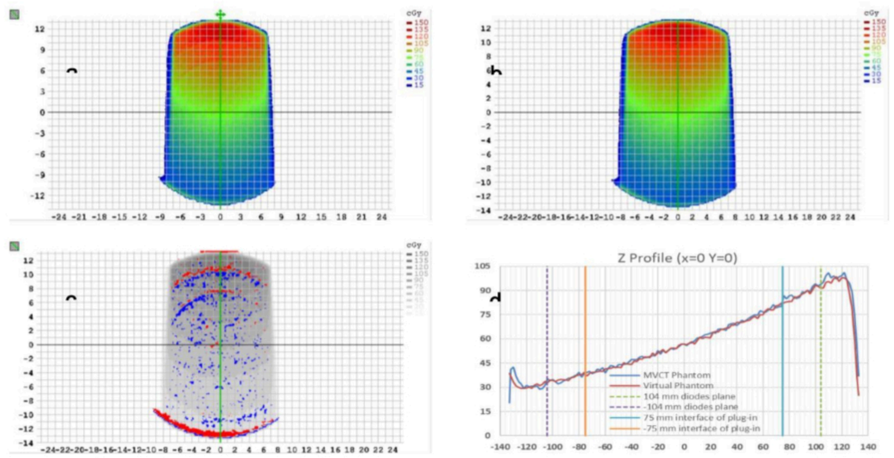

Figure 3. Gamma analysis of planned dose for a simple field of 15 × 15 cm² in transverse plane calculated with (a) MP and (b) VP_m. (c) Hot and cold spots with criterion of 2%/2mm and (d) the Z profile along the bean axis. The positions of incident and outgoing diodes plane and interface of plug-in are marked by color lines .

The hot spots were mainly concentrated at the incident detector layer and plug-in interface as well as outgoing surface of the phantom. While at the outgoing detector surface, there were lots of cold spots.

This effect cannot be corrected by simply adjusting the RED of the virtual phantom, because the adjustment of VP's RED would lead the planned dose of the incident and outgoing detector layer increase or decrease at the same time.

CONCLUSIONS

For conventional linac, both MVCT phantom and virtual phantom can be used for machine and patient specific QA. However, for MR-linac, virtual phantom and the method of adjusting its RED to achieve higher gamma pass rate are not recommended, because the exacerbated effect of nonuniform RED distribution near the detector layer on the planned dose calculation should be taken into account in the presence of magnetic field.

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