OCTAVIUS® based plan verification

at a MRIdian® linac

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Introduction

A workflow is presented to perform measurement-based patient plan verification on the MRIdian® MR linac system with OCTAVIUS® II phantom and air-filled OCTAVIUS® 1500 MR or liquid-filled OCTAVIUS® 1600 MR ionization chamber array. For this purpose, the approach from Mönnich et al [1], showing the workflow at the Elekta Unity MR linac, was adapted to the MRIdian system.

In a first step, angular ranges were defined in which the arrays in the OCTAVIUS® II phantom can be irradiated with no significant angular impact. This step is performed once and does not have to be repeated by the user. In the second step, treatment plans were verified and the clinical workflow was described.

The OCTAVIUS® II phantom with CT phantom body (red smiley face) was used for all measurements, as this phantom type has no air cavities but consists of a homogeneous volume.

Angular response

Each array was positioned in the OCTAVIUS® II phantom and the phantom was positioned at the laser system, such that the center of the array within the phantom center was placed in the machine isocenter. The phantom was positioned in four orientations as shown in Figure 1 and for each orientation the phantom was irradiated from 15 angles in 10° steps. Both arrays were irradiated with a 10 cm x 10 cm field with 100 monitor units for each gantry angle.

Figure 1: Phantom positions: Top, right, bottom, left

A cross calibration was performed with the measurement at 0° gantry angle against the TPS calculation performed at 0° using the central ionization chamber result. In order to analyze the angular dependence, each measurement was compared against the planned dose distribution using Verisoft 8.1. The gamma algorithm implemented in Verisoft with parameter "local" and 3 % / 3 mm criterion was used as comparison criterion. The analyzed gamma passing rates for each phantom position and array type are shown in Figure 2. This results in the following angular ranges shown in Table I. In summary, treatment plans need to be divided into these four areas and verified in four sequential array measurements.

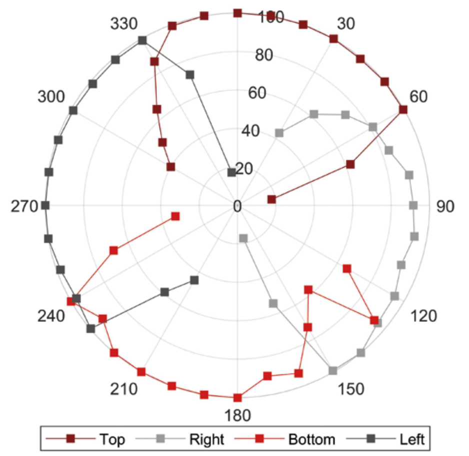


Figure 2: Angular response of OCTAVIUS® 1500 MR array in OCTAVIUS® II phantom. Phantom was aligned in four positions according to Figure 1.

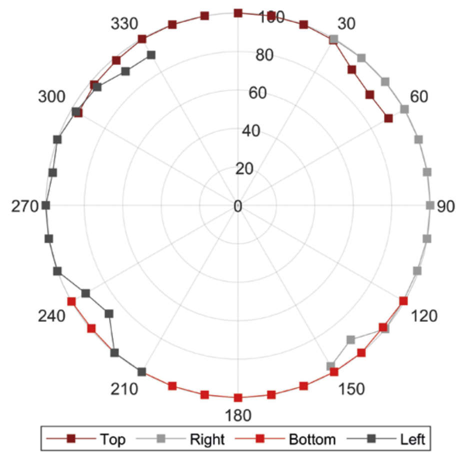
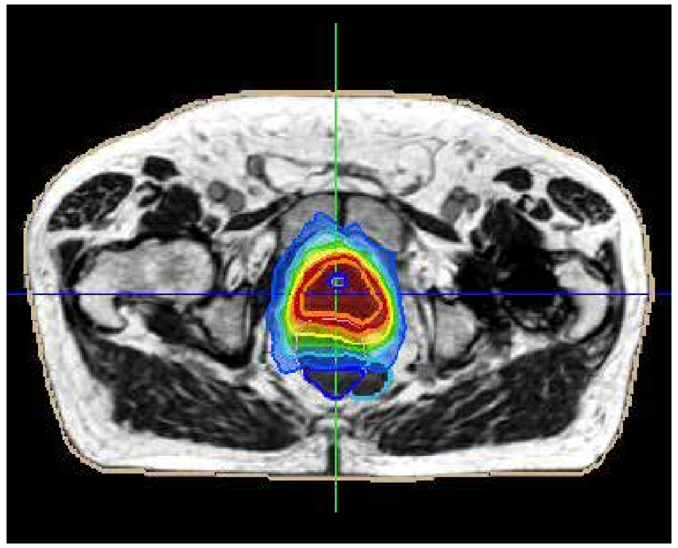


Figure 3: Angular response of OCTAVIUS® 1600 MR array in OCTAVIUS® II phantom. Phantom was aligned in four positions according to Figure 1.

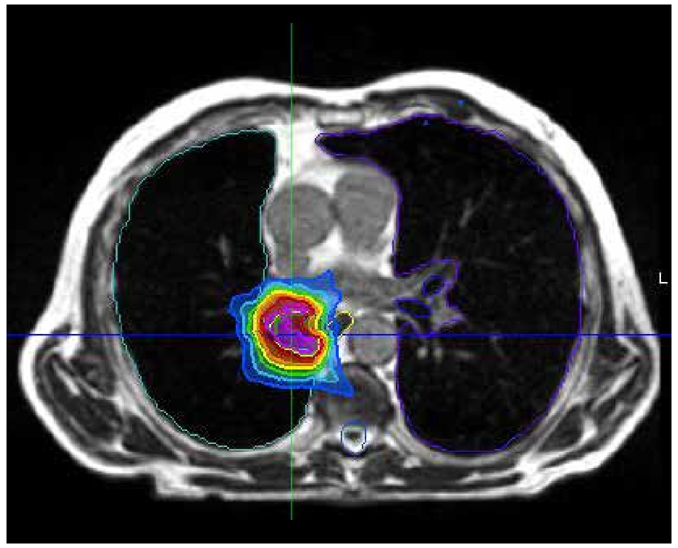
Phantom position	Gantry range OCTAVIUS® 1500 MR	Gantry range OCTAVIUS® 1600 MR
Top	331 - 60	331 - 60
Right	61 - 150	61 - 150
Bottom	151 - 240	151 - 240
Left	241 - 330	241 - 330

Table I: Angular ranges for QA plans according to the phantom positioning

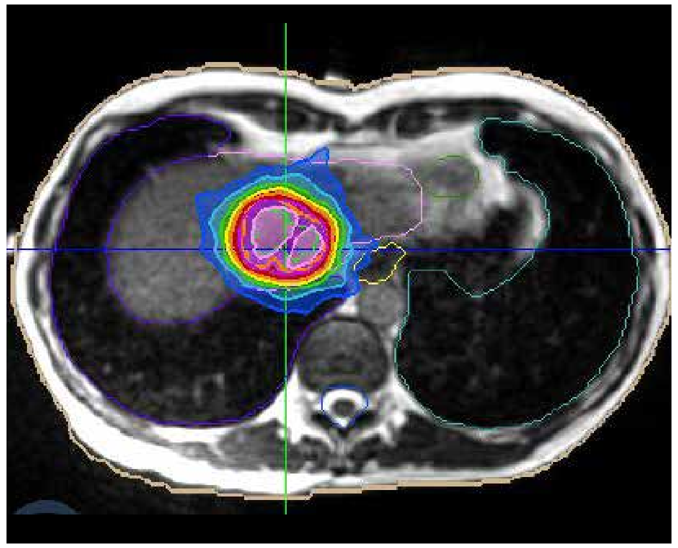
Plan verification



Prostate



Lung



Liver

Figure 4: Verified patient treatment plans: Prostate, Lung, Liver.

Three stereotactic treatment plans (prostate, lung, liver) as shown in Figure 4 were verified using the presented approach: The prostate treatment plan was planned with a median dose of 37.5 Gy in 5 fractions; the lung plan was prescribed with 55 Gy to the 80% isodose in 10 fractions and the liver case was treated with 60 Gy to the 80% isodose in 8 fractions.

Each treatment plan was divided into four individual QA plans covering the angular ranges described in Table I. An example of the process is shown in Figure 5. The OCTAVIUS® II phantom equipped with a PTW array was positioned sequentially in all four orientations in the bore. The four QA plans were irradiated and saved as individual mcc files. For cross calibration a 10 cm x 10 cm field from 0° was irradiated in the "top" position.

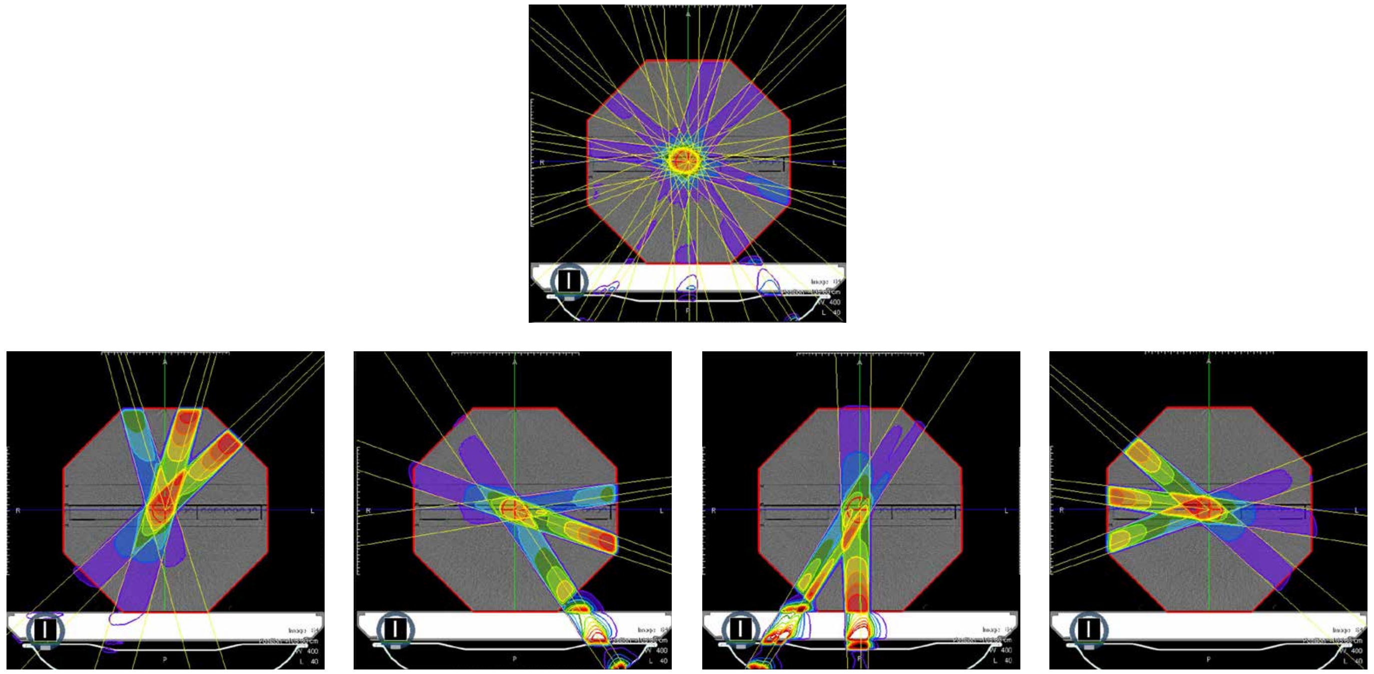
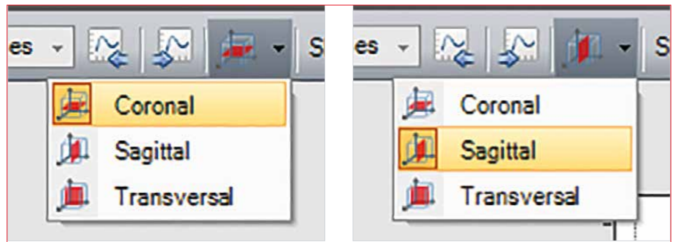
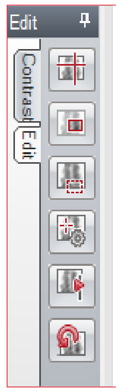
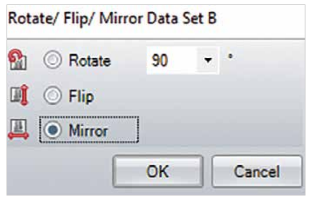


Figure 5: Liver QA treatment plan. Top: Treatment plan calculated on OCTAVIUS® phantom CT with all gantry angles. Bottom: four individual QA-plans covering the angular ranges described in Table I.



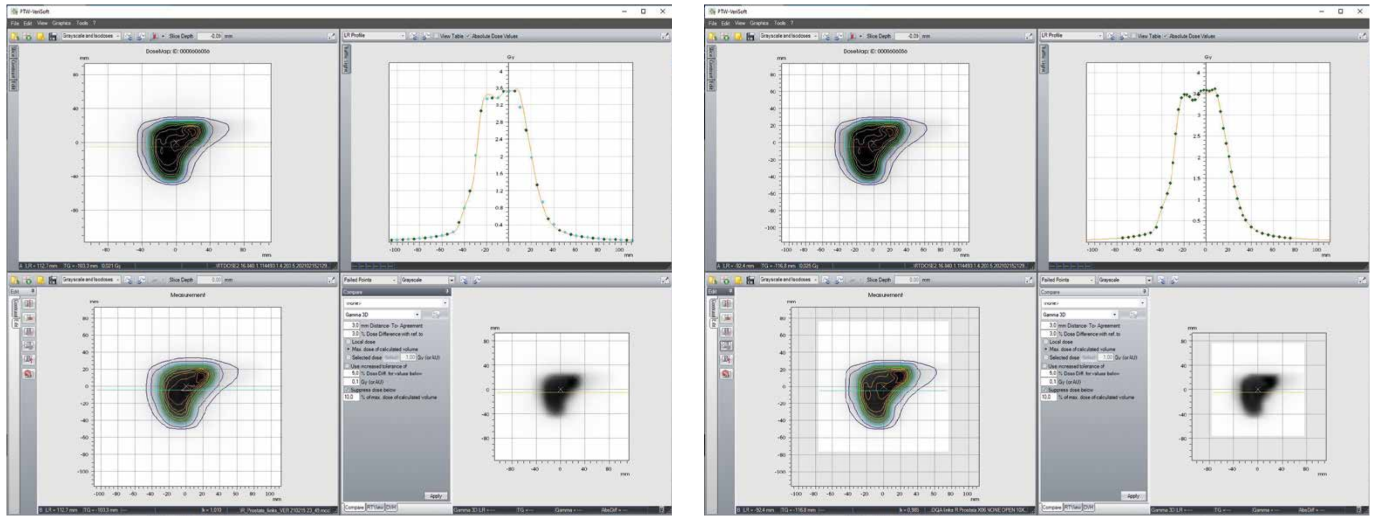
Note:
DICOM in sagittal view for "left" and "right" position and in coronal view for "top" and "bottom" phantom position



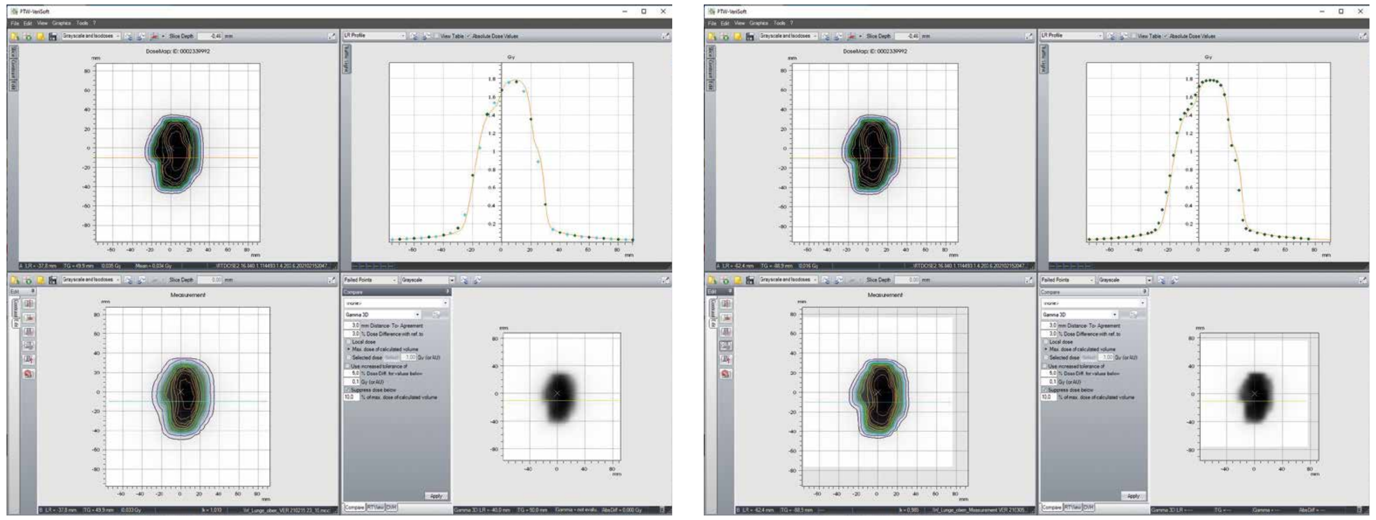


Note:
Mirror the array data in "bottom" and "left" phantom position due to the different phantom positions

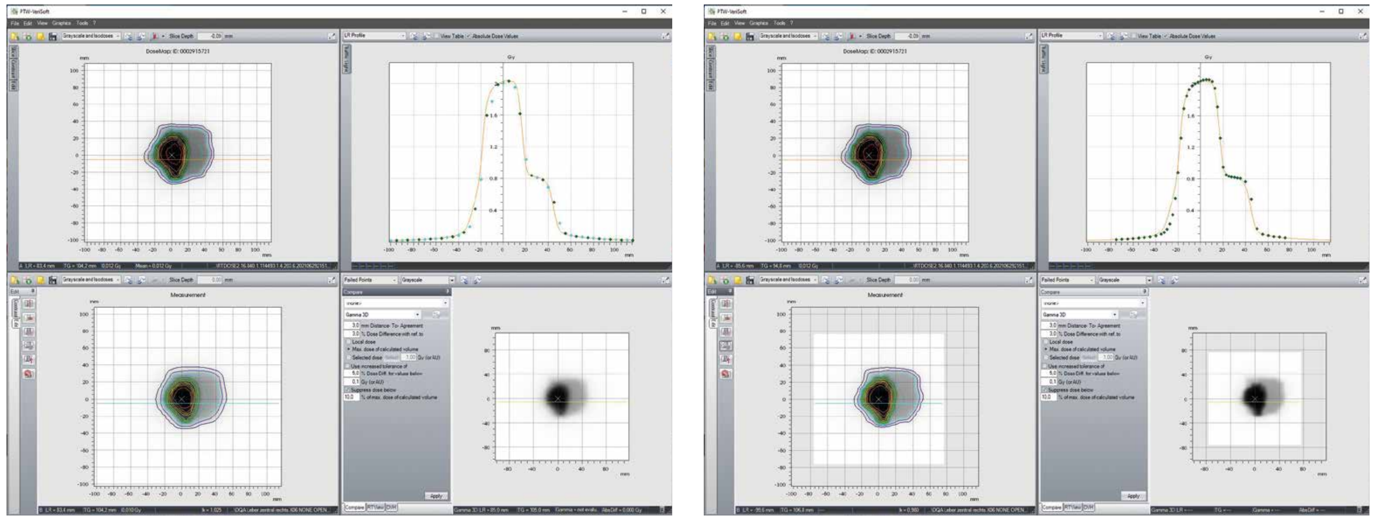
For the comparison between TPS calculation and measured dose in Verisoft, it is necessary to mirror the array data in "bottom" and "left" phantom position due to the different phantom and detector orientations. The TPS DICOM data must be displayed in sagittal view for "left" and "right" position and in coronal view for "top" and "bottom" phantom position, due to the different orientations of the array in each position.
All datasets were analyzed with Verisoft 8.1. using the 3D Gamma algorithm and 2 % / 2 mm and 3 % / 3 mm criteria with "global" option and 2nd and 3rd pass option turned on. Dose below 10 % of the maximum dose was suppressed. The passing rates for each phantom position are shown in Figure 8 (OCTAVIUS® 1500 MR) and Figure 9 (OCTAVIUS® 1600 MR) in grey colors. With 3 % / 3 mm gamma criterion, both arrays show a pass rate of more than 98 % in all phantom positions. With a gamma criterion of 2 % / 2 mm, the 1600 MR array also shows a pass rate of more than 98 % in nearly all positions except for one. Figure 6 shows six examples with 3 % / 3 mm gamma criteria for single phantom positions for both arrays and all treatment plans. In all cases the array measurement represents the calculated dose distribution. Failed points were only observed at the outer region of the target volume. Due to its higher resolution, the OCTAVIUS® 1600 MR array shows a more detailed representation of the selected profile.



Prostate plan and phantom position "left"



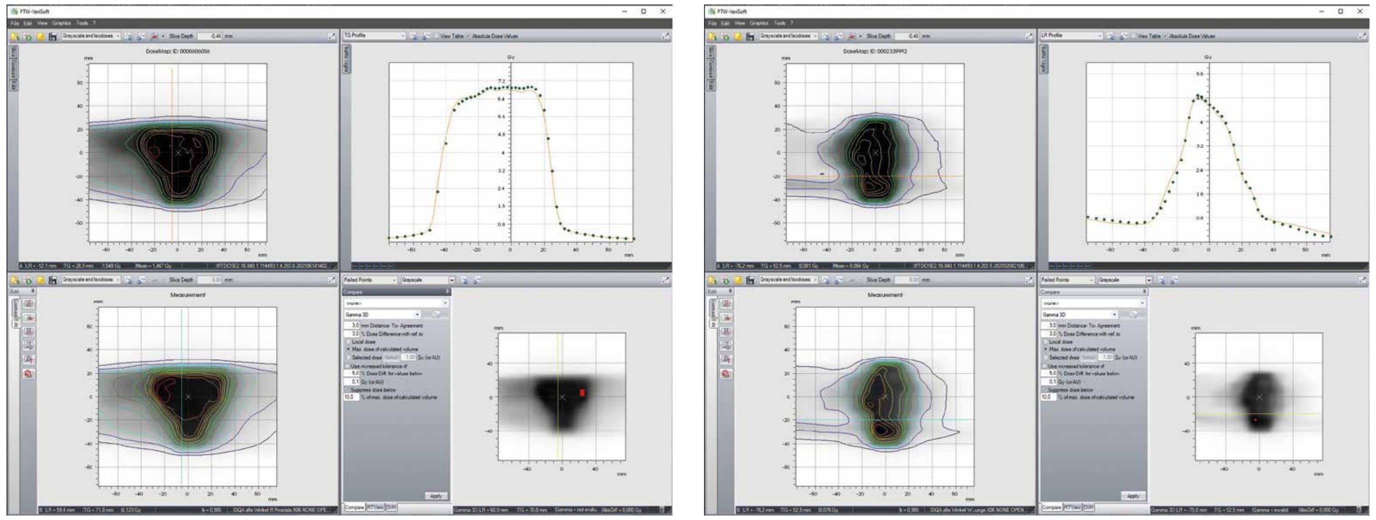
Lung and phantom position "top"



Liver and phantom position "right"

Figure 6: Comparison between measured plan and calculated QA plan for a single phantom position. Left column: OCTAVIUS® 1500 MR array, right column: OCTAVIUS® 1600 MR array. Comparison is shown for a single profile analyzed with 3 % / 3 mm gamma criteria.

It can be observed in Figure 3, that the angular dependence of the OCTAVIUS® 1600 MR array in the phantom is very low. Due to this behavior, an additional approach was conducted to verify the patient plans without phantom rotation. For this purpose, the plan was irradiated to the OCTAVIUS® 1600 MR array in its original configuration in phantom "top" position without splitting the plan into 4 individual QA plans. The passing rates are shown in Figure 9 (OCTAVIUS® 1600 MR) in red color. The results are comparable to those of the split approach. Figure 7 shows evaluations of single profiles typical for each treatment plan.



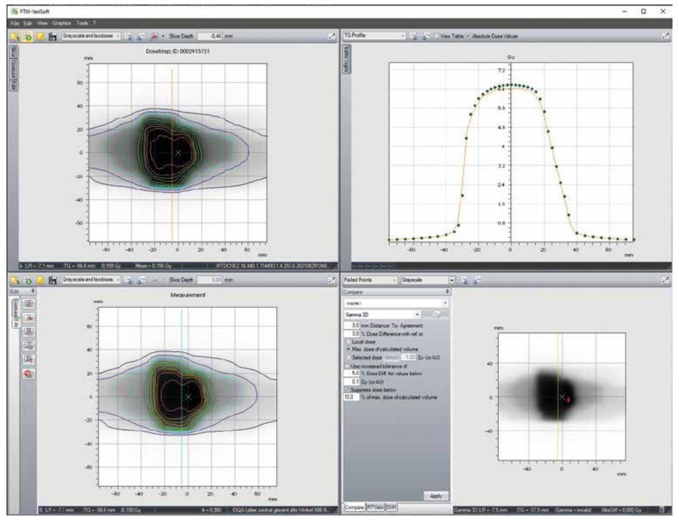


Figure 7: Comparison between measured plan with OCTAVIUS® 1600 MR array and calculated QA plan for measurement of all gantry angles with phantom "top" position. Comparison is shown for a TG profile analyzed with 3 % / 3 mm gamma criteria. First row left: prostate, first row right: lung, second row left: liver.

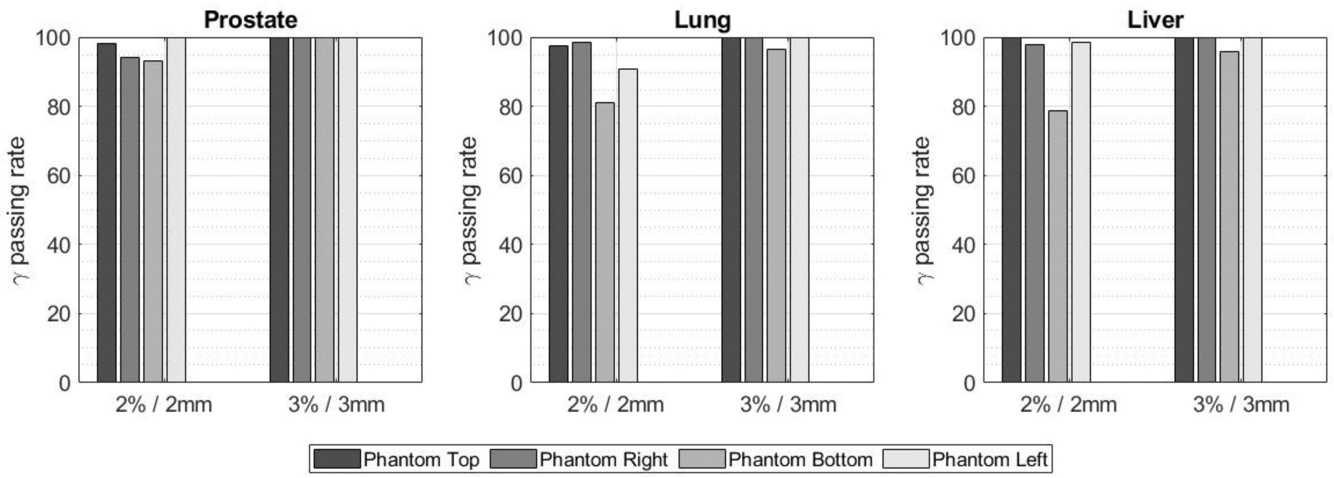


Figure 8: OCTAVIUS® 1500 MR array: Gamma passing rates for prostate, lung and liver treatment plans analyzed with 2 % / 2 mm as well as 3 % / 3 mm criteria. Grey bars show results of the split approach with different phantom positions and four QA plans.

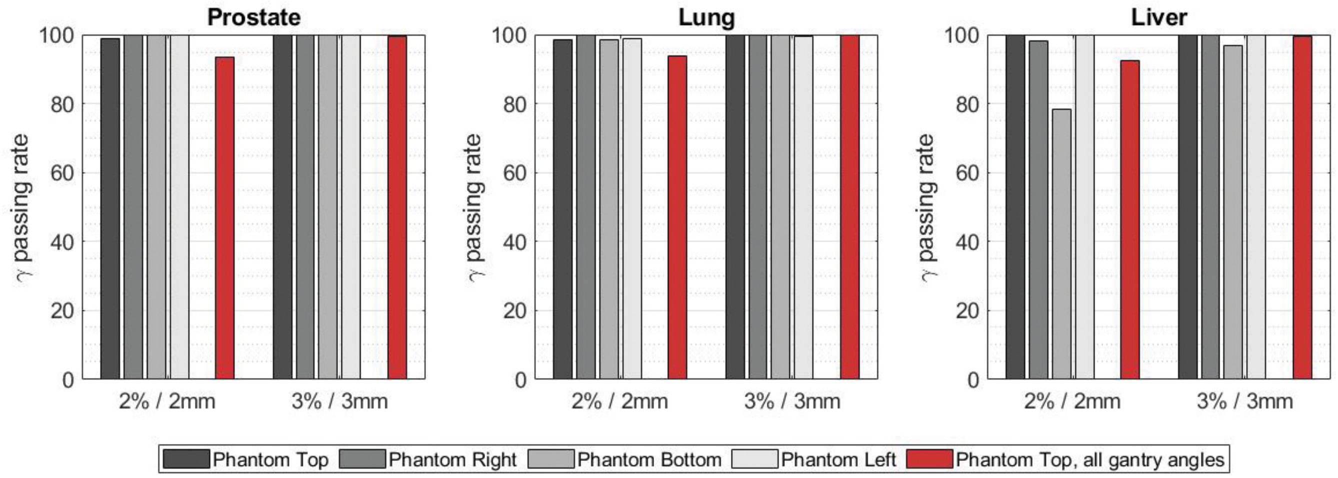


Figure 9: OCTAVIUS® 1600 MR array: Gamma passing rates for prostate, lung and liver treatment plans analyzed with 2 % / 2 mm as well as 3 % / 3 mm criteria. Grey bars show results of the split approach with different phantom positions and four QA plans, red bars show results of one measurement without different phantom positions.

Conclusion

An approach to measurement-based plan verification on MRIdian® systems using OCTAVIUS® II phantom and OCTAVIUS® 1500 MR or OCTAVIUS® 1600 MR array was presented. The approach is a modified approach from Mönnich et al [1]. Splitting a patient plan into four QA plans, a patient plan can be verified with both array types and OCTAVIUS® II phantom. In addition, it was investigated whether the plan can be completely irradiated to the OCTAVIUS® 1600 MR array in a single phantom position omitting the need for splitting the plan.This work presents a complement to the study of Mönnich et al. [1] proving that the OCTAVIUS® II phantom in combination with the OCTAVIUS® 1500 MR or OCTAVIUS® 1600 MR array present a straightforward, easy-to-use alternative for plan verification measurements at MR linacs.

References

[1] Mönnich D, Winter J, Nachbar M, Künzel L, Boeke S, Gani C, Dohm O, Zips D and Thorwarth D: Quality assurance of IMRT treatment plans for a 1.5 T MR-linac using a 2D ionization chamber array and a static solid phantom, Phys. Med. Biol. 65, 2020

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