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Validation of a Non-Isocentric Positioning of the ArcCHECK System for Patient-Specific QA on a 0.35 T MR-Linac

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INTRODUCTION

In 2019, the MRIdian, Viewray MR-Linac has been installed at the Georges-François Leclerc Center providing magnetic resonance-guided radiation therapy (MRgRT) [1]. This machine makes possible the gating of the tumor based on continuous MR imaging and includes a daily plan adaptation process. Thanks to these new tools, a better control of the tumor position and a better sparing of the organs at risk are possible. Therefore, digestive tumors that are often surrounded by high sensitive organs at risk are mostly treated on this machine.

Many of theses tumors are lateralized, specially for liver. Nevertheless, because of the limited size of the tunnel of our MR-linac, the centering of target volumes on the isocenter of the machine is not always possible. Consequently, the isocenter of the machine is often out of the target volume [Fig. 1].

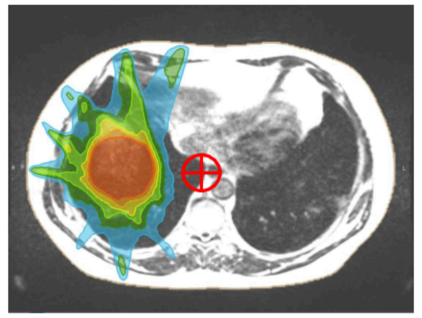

Fig. 1 : Lateralized tumor distant from the machine isocenter

AIM

On the MRIdian, our Patient-Specific QA (PSQA) are performed using the ArcCHECK, Sun Nuclear (AC) system. In order to ensure a proper functioning, the manufacturer recommends to have an isocentric positioning of the AC. In this position, the AC has already been used and validated on this facility [2].

However, in the context described in the introduction, the lateral shifting of the AC seems appropriate to maximize the detection of relevant levels of dose.

According to the angles of irradiation, correction factors are applied to the signal measured with the AC. The AC has its proper irradiation angle detection algorithm. **The main issue by shifting laterally the AC is to impact the correct detection of the beam angles and corrupt the results with non-adapted correction factors.**

This work aims to investigate, evaluate and validate the use of the AC system for a non-isocentric and lateralized positioning.

METHOD

In a first approach, the **angular correction factor** table from SNC Patient software controlling the AC has been investigated. These factor are applied to the measurement performed each 0.05 ms. In order to quantify the impact of an angle detection error, relative differences for correction factors have been calculated for misdetection of ±5° and ±10°.

In a second step, for **two liver treatment plans** (with the center of the PTV shifted about 6 cm from the isocenter), we performed PSQA for 0, 2, 4, 6 cm AC shifting [Fig.2]. We systematically analyzed:

- the 2%/2 mm index gamma passing rate with a 10% dose threshold [3];
- the irradiation angles detected compared to those planned;
- the number of diodes included into the analysis.

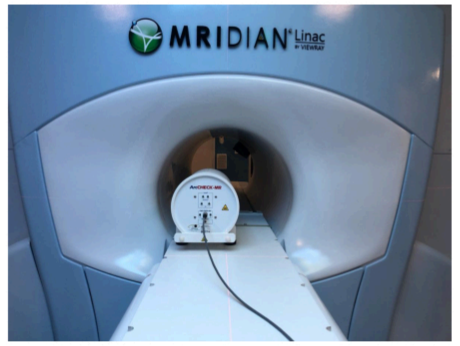

Fig. 2 : Lateral positioning of the AC in the MRIdian, Viewray

RESULTS

Angular correction factor

On figure 3, for different level of angle detection errors, the relative difference on the angle correction factor is plotted according to the angle of irradiation.

For an angle detection error contained between ±5°, the maximum correction factor deviation is around 0.8% and is mostly lower than 0.5%.

For an angle detection error contained between ±10°, the maximum correction factor deviation is around 1.6% and is mostly lower than 1.0%.

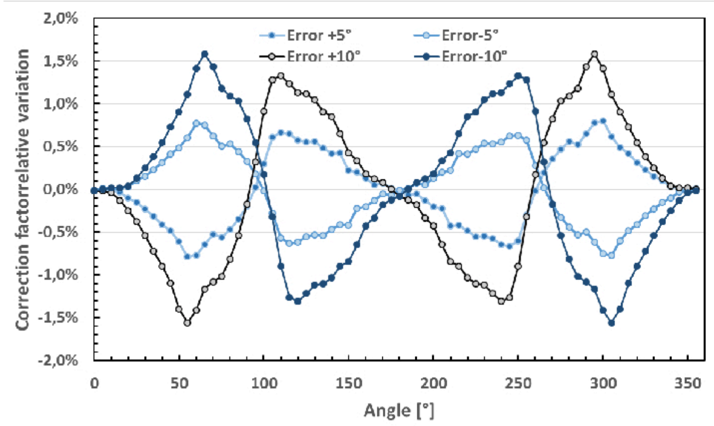

Fig. 3 : Relative error induce on the correction factor by ±5° and ±10° angular error

The difference on the angular correction induced by the presented errors seems to be quite limited (< 1%).

If the angle detection errors are contained in between the presented values, the impact on PSQA result will mainly depend on the amount of errors during the irradiation.

Clinical evaluation: focus on liver treatment plans

The figure 4 is an illustration of the dose distribution difference for an isocentric and non-isocentric positioning of the AC for the same liver treatment plan.
The dose distribution has been calculated with the dedicated Viewray treatment planning system for step-and-shoot IRMT.

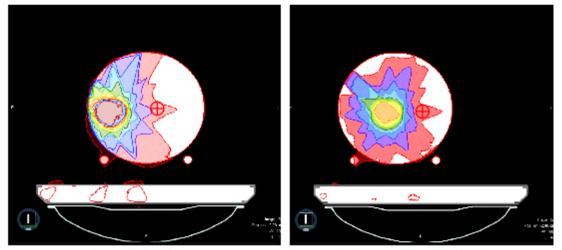

Fig. 4 : AC PSQA configuration for without shifting (left) and with 6 cm lateral shifting (right)

AC shift [cm]	2%/2 mm Global	2%/2 mm Local
0	98.0%	93.7%
2	97.3%	95.1%
4	95.7%	93.2%
6	97.2%	94.4%

Fig. 5 : Gamma index pass rate according to the lateral AC shift

The figure 5 is a table of gamma index pass rates obtained according to the AC shift. The analysis performed with the criteria of 2%/2 mm always shows high pass rates.
The lateral shift seems to not change significantly the result.

For each measurement performed at a frequency of 20 Hz with the AC, the detected angle has been compared to the planned one. **Whatever the shift, it appears that no error higher than ±5° has been observed.** Systematic errors around ±1° have been often observed due to set up and algorithm uncertainties. This observation explains the lack of influence of the shift on PSQA results.

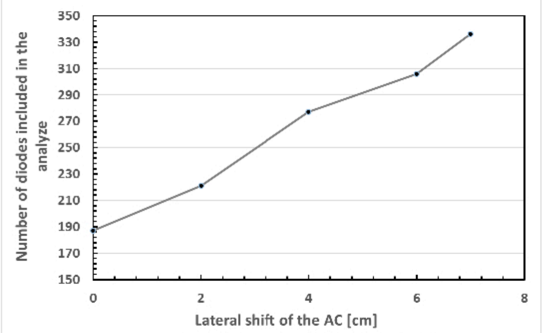

Fig. 6 : Number of diodes included in the analysis according to the lateral shift of the AC

In parallel, **the shifting of the AC has highlighted a logical increase of the number of diodes included in the gamma index analysis**. The figure 6 illustrates this observation in particular with a +80% relative increase between a non shifted and a 6 cm shifted positioning. The inclusion of more diodes makes the PSQA more consistent and relevant for the control of each beam. The figure 4 also illustrates this improvement.

CONCLUSIONS

This study is a first satisfying step for the validation of a shifted use of the AC system for PSQA of lateral tumor treatment plans distant from the isocenter on the MRIdian, Viewray MR-Linac.

The irradiation angle detection has been investigated according to the introduced shift. Even for a relative important shift of the AC, the detection errors stay limited in number of measurements and in level error.

Consequently, no significant impact on the gamma index pass rate of the PSQA has been observed. For criteria of 2%/2 mm, the pass rates stay higher than 93.2% and 95.7%, respectively, for local and global gamma index.

In parallel, a significant increase of the proportion of the 1386 diodes of the AC included in the analysis has been observed. Up to 80% additional diodes have been included in the analysis making the PSQA more relevant and representative of the treatment.

This work has to be continued for more treatment plans in order to completely validate this use.

Besides, it could be interesting to investigate the lateral use of the AC on others radiotherapy facilities built with a tunnel.

REFERENCES

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