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Evaluation of an integral quality monitor device for monitoring real-time delivery

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Introduction

Radiotherapy treatments are getting more and more complex, thus it is of increasing importance to monitor delivered beams to identify errors. This study analyze the use of a linac-head integral quality monitor (IQM, iRT Systems GmbH) for real-time beam delivery control. We evaluate IQM beam attenuation and its ability in detecting VMAT delivery errors.

Materials and Methods

Beam attenuation was calculated at 4 different beam size (from 5x5 to 20x20 cm^2) by the IC Profiler (Sun Nuclear Corp.) at 6 MV and 10 MV beam energies in both X and Y directions.

The IQM capability in recognizing errors was performed introducing deviations in 4 clinical H&N VMAT plans: 3, 5 and 10 % errors on total delivered MUs and 3, 5 and 10 mm MLCs shift by means of an homemade Matlab (MathWorks, Natick, MA) script. The cumulative IQM checksum value was measured and the percentage difference was calculated with respect to the non-modified plan.

At the same time we obtained dose distribution maps through the PTW 2D array inserted in a rotating QA phantom (RT-smartIMRT, dose.point GmbH). The phantom was chosen for its geometrical characteristics similar to IQM in signal recollection (Figure 1). The local gamma pass rates (2%/2mm) were compared to the original plan values.
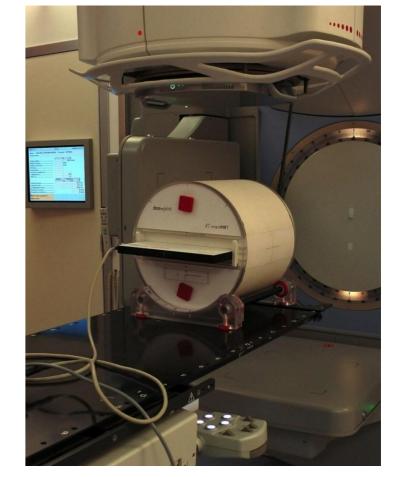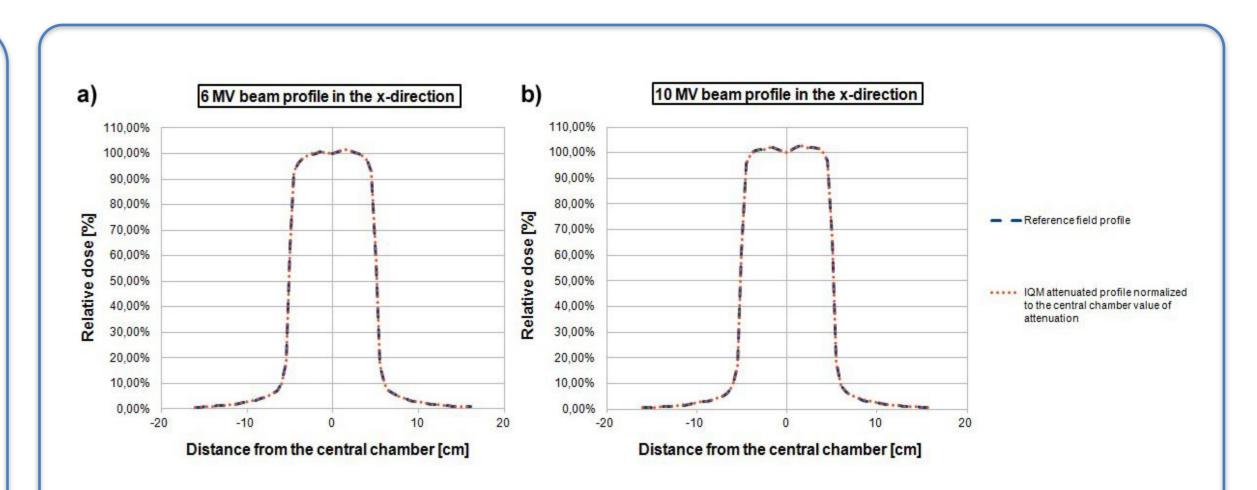
Figure 1. Experimental setup: linac-head integral quality monitor (IQM) and RT-smartIMRT phantom

Results

Beam attenuations were normalized to the central chamber of IC Profiler. It gives average attenuation values of 6.56 % ± 0.03 % and 5.27 % ± 0.12% for 6 MV and 10 MV beams, respectively. Flatness deviation is < 0.4 % for 6 MV and < 0.1 % for 10 MV excluding beam penumbra regions. The beam profiles in the X direction for a 10x10 cm^2 field are depicted in Figure 2 for 6 MV (Figure 2a) and 10 MV (Figure 2b) beams. The reference field profile (blue line) is plotted with the IQM attenuated field normalized to the central chamber attenuation value (orange line).

Results for modified VMAT plans are summarized in Figure 3. Figures 3a and 3b show the gamma pass rates (±SD) and the IQM signal percentage differences (±SD) for MUs variations, respectively. Figures 3c and 3d illustrate the results (±SD) for MLCs shift.

Both methods detect specifically MLC shift errors, while MUs variations were better identified by IQM. IQM shows a linear response with dose (R^2=0.9995), while gamma analysis seems to have difficulty in identifying 3% and 5% MUs variations. In our opinion the reason is that the RT-smartIMRT recollect a 2D dose map as if the entire plan were delivered at a fixed gantry angle. Further comparisons to gamma analysis should be evaluated with a different kind of phantom.

Figure 2. Beam profiles in the X directions for a 10x10 cm^2 field for: **a)** 6 MV photon beam; **b)** 10 MV photon beam. The reference field profile (blue line) is plotted with the IQM attenuated field normalized to the average attenuation value (orange line).
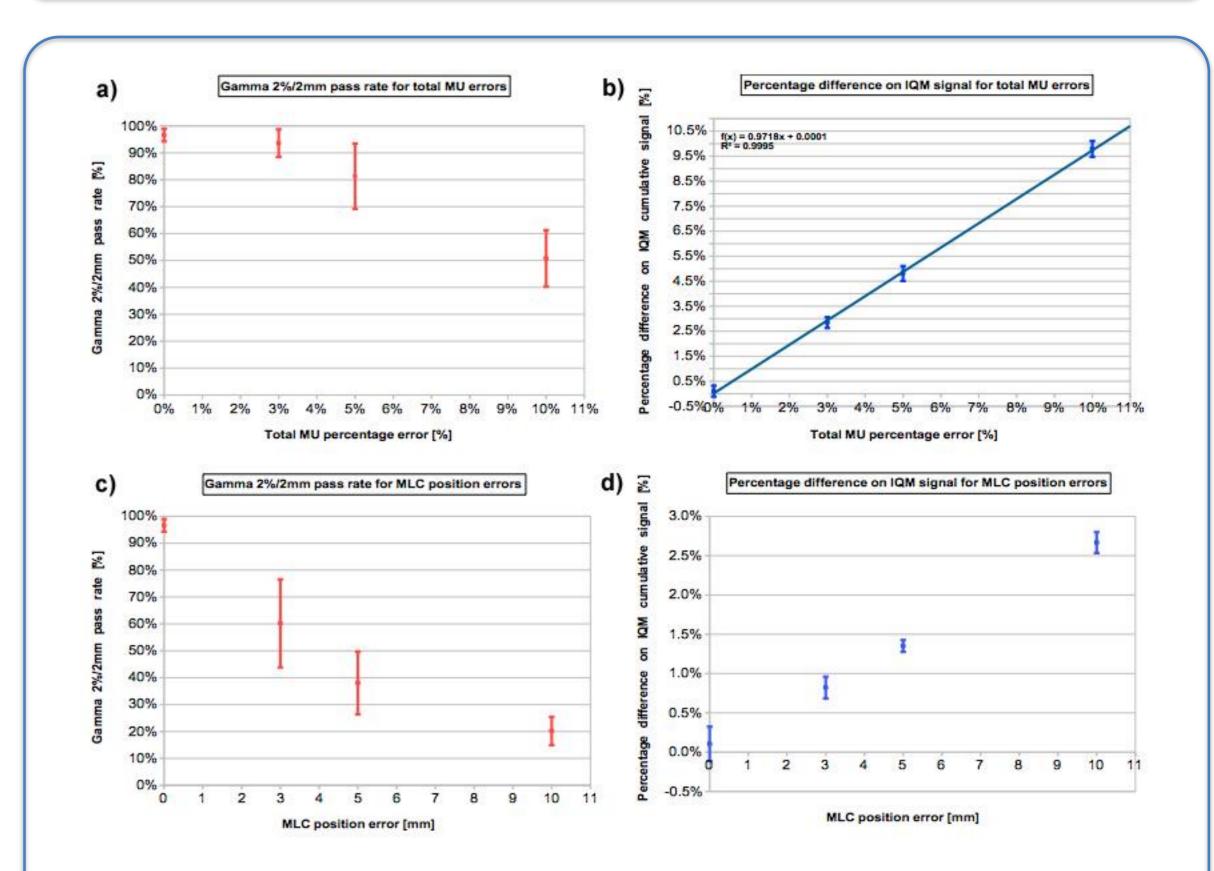
Figure 3. Results for VMAT plans: **a)** Gamma pass rates for MUs variations; **b)** IQM signal percentage differences for MUs variations; **c)** Gamma pass rates for MLCs shift; **d)** IQM signal percentage differences for MLCs shift.

Conclusion

IQM beam attenuation can be considered to be homogenous in both X and Y directions and the machine-specific beam attenuation percentage could be used to rescale treatment plan dose for clinically IQM use. IQM shows appreciable features in detecting real-time errors and for time-saving QAs, although the characterization of IQM response to single segment errors still have to be analyzed.

1) Islam M. K. et al. *An integral quality monitoring system for real-time verification of intensity modulated radiation therapy*. Med Phys 2009, 36(12): 5420-5428;
2) Chang J. et al. *A method for online verification of adapted fields using an independent dose monitor*. Med Phys 2013, 40(7): 072104-1 – 072104-8.

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