JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

# A simple statistical method to reduce the number of patient-specific quality assurance measurements for MR-Linac adaptive fractions


Anthony Kim[1,2], Mark Ruschin[1,2], Claire McCann[1,2], Philip Au[1], Amritpal Singh[1], Arjun Sahgal[1,2], Brian Keller[1,2]

1 Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

2 University of Toronto, Department of Radiation Oncology, Toronto, Ontario, Canada


Sunnybrook HEALTH SCIENCES CENTRE

## INTRODUCTION

The 1.5 T MR-Linac is a recently released treatment platform that can handle online adaptation using daily MR images.[1,2,3]

When we began treating with the MR-Linac, we performed patient-specific QA measurements with a commercial helical diode array phantom for each adapted fraction.

QA measurements pass with a gamma>95% with the plan/measurement dose distributions matching within 3%/3mm.

We realized that measuring every fraction was an impractically high workload (e.g. brain patients are treated with 30 fractions). Hence, we now use a statistical tool—the confidence interval for the mean—to justify measuring only the initial reference plan and the first adapted fraction.

## AIM

To demonstrate a statistically robust method to reduce the number of MR-Linac patient-specific QA measurements.

## METHOD

A confidence interval is a range of values that we are reasonably sure our true mean is in.

With MR-Linac patient-specific QA measurements, it is satisfactory if the mean of all of the gamma pass rates in a course is >95%.

To use this method, we needed a representative standard deviation for brain patients.

This data comes from our first five brain patients, where approximately half of all fractions were measured (81 measurements).

For each patient the standard deviation of the gamma pass rate was calculated.

The confidence interval was used to predict from just a few measurements if the average pass rate in the course will pass QA.

## RESULTS

Figure 1 shows the measurement phantom on the MR-Linac, and an example of the dose map that is acquired by the helical diode array.

For the 5 patients, the gamma standard deviations ranged from 0.0%-0.6% when calculated for each patient. 0.6% was selected as the worst case value for the confidence interval calculator. Entering in the first two measurements for the five patients, the calculator returns 99.9% confidence intervals.

Figure 2 displays a sample 99.9% confidence interval calculation for patient #2 for the reference and 1st adapted fraction. This calculator can be expressed as shown in Table 1, where more fractions measured requires a lower average gamma pass rate to land within the 99.9% confidence interval.

Table 1 shows confidence intervals for the five patients. Figure 3 shows a graph showing all gamma pass rates for patient #2 as well as the confidence interval, and shows that the true mean lies within the confidence interval.

In Table 1, for all 5 patients only two QA measurements are needed to confirm that the confidence interval is above the 95% threshold. Suppose the confidence interval ranged partially <95%; then more measurements would be needed until the confidence interval is >95%.

This demonstrates that two measurements are needed for these patients in order to have the confidence to proceed with the treatment without further QA measurements, a drastic decrease in patient-specific QA workload.

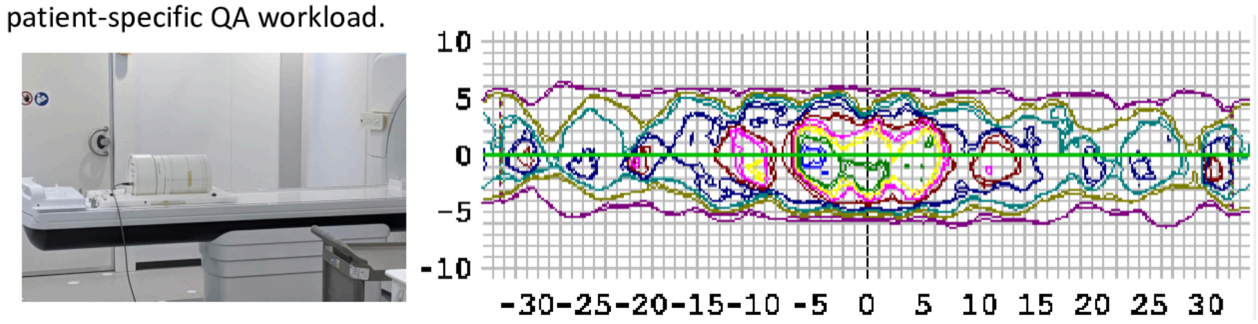
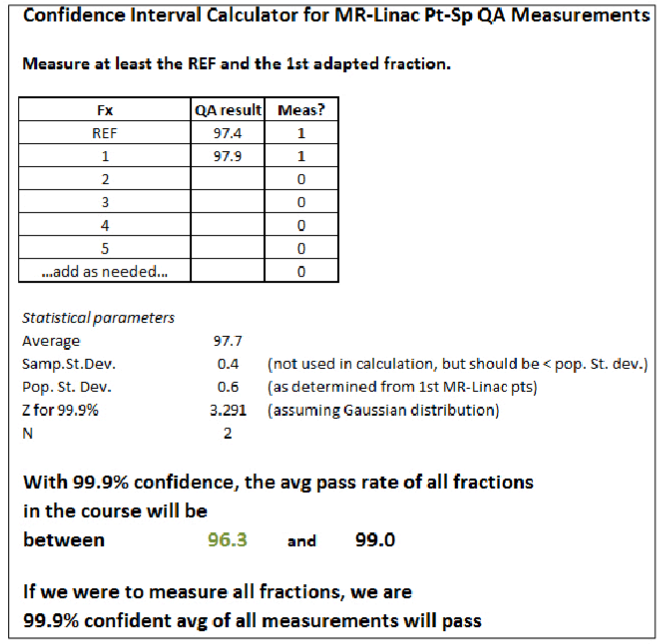



Figure 1: (Left) Patient-specific QA phantom on the MR-Linac couchtop before sending it into the treatment/imaging bore; (Right) Typical dose map measured by the phantom compared with the TPS calculation on the phantom.



Confidence Interval Calculator for MR-Linac Pt-Sp QA Measurements

Measure at least the REF and the 1st adapted fraction.

| Fx | QA result | Meas? |
|---|---|---|
| REF | 97.4 | 1 |
| 1 | 97.9 | 1 |
| 2 | | 0 |
| 3 | | 0 |
| 4 | | 0 |
| 5 | | 0 |
| ...add as needed... | | 0 |

*Statistical parameters*

| | | |
|---|---|---|
| Average | 97.7 | |
| Samp.St.Dev. | 0.4 | (not used in calculation, but should be < pop. St. dev.) |
| Pop. St. Dev. | 0.6 | (as determined from 1st MR-Linac pts) |
| Z for 99.9% | 3.291 | (assuming Gaussian distribution) |
| N | 2 | |

With 99.9% confidence, the avg pass rate of all fractions in the course will be between 96.3 and 99.0

If we were to measure all fractions, we are 99.9% confident avg of all measurements will pass

Figure 2: Confidence interval calculator applied to patient #2's first two measurements (i.e. the reference plan and first adapted fraction);.

| # of measurements | Threshold of A (avg of measurements) for 99.9% confidence that avg of all pass rates>95% |
|---|---|
| REF+1 Adp't fx | 96.5% |
| REF+2 Adp't fxs | 96.1% |
| REF+3 Adp't fxs | 96.0% |
| REF+4 Adp't fxs | 95.8% |
| REF+5 Adp't fxs | 95.8% |

Table 1: Thresholds of the average gamma pass rates required for 99.9% confidence that the putative average of all pass rates in the course will be >95%.

| | Gamma pass rate (%) | | Confidence calculator range | | |
|---|---|---|---|---|---|
| Pt # | REF | 1st fraction | Lower | Upper | True mean |
| 1 | 100 | 100 | 98.6 | 100 | 100.0 |
| 2 | 97.4 | 97.9 | 96.3 | 99 | 97.0 |
| 3 | 100 | 99.8 | 98.5 | 100 | 100.0 |
| 4 | 100 | 99.8 | 98.5 | 100 | 99.9 |
| 5 | 100 | 100 | 98.6 | 100 | 100.0 |

Table 2: Gamma pass rates for the reference plan and first adapted fraction, and the predicted range from the confidence calculator (lower and upper values) and the true mean calculated from all fractions per patient. The true mean is always within the predicted range from the confidence calculator.

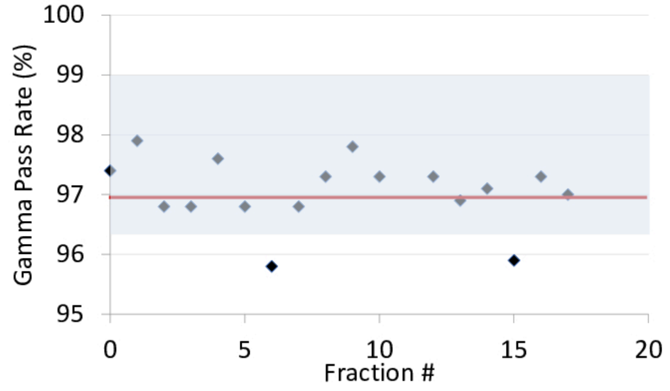



Figure 3: Patient #2's measurements plotted against fraction #, with the true mean (solid line at 97%) and the confidence interval (shaded region 96.3%-99.0%) overlaid on the graph.

## CONCLUSIONS

We have demonstrated a method to calculate the confidence interval of gamma pass rates for an MR-Linac course, relying upon the first 2-5 measurements.

At this writing, there are 13 1.5 T MR-Linacs in clinical operation in the world. Some facilities are performing patient-specific QA measurements for every fraction, which is a very heavy workload.

Our method provides a statistically sound framework to confidently eliminate the majority of these measurements in clinical practice, which is a highly practical tool in a busy clinic.

## REFERENCES


1. Raaymakers BW, Jürgenliemk-Schulz IM, Bol GH, et al. First patients treated with a 15 T MR-Linac: clinical proof of concept of a high-precision, high-field MRI guided radiotherapy treatment. Phys Med Biol. 2017; 62(23): L41-L50.
2. Lim-Reinders S, Keller BM, Al-Ward S, Sahgal A, Kim A. Online Adaptive Radiation Therapy. Int J Radiat Oncol Biol Phys, 2017; 99(4): 994-1003.
3. Kim A, Lim-Reinders S, McCann C, Ahmad S B, Sahgal A, Lee J and Keller BM. Magnetic field dose effects on different radiation beam geometries for hypofractionated partial breast irradiation. J Appl Clin Med Phys. 2017; 18(6): 62-70.


## ACKNOWLEDGEMENTS


We would like to acknowledge the Radiation Therapy MR-Linac team of Shawn Binda, Anne Carty, Susana Sabaratram, Christina Silverson, Helen Su, Thanh Truong, Katie Wong, and Danny Yu.


## CONTACT INFORMATION


Anthony Kim
Email: Anthony.Kim@sunnybrook.ca