Clinical Experience Implementing an Ion Chamber Array for Monthly Beam Constancy Versus Ion Chamber in Water

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INTRODUCTION

The AAPM TG142 report recommends monthly linear accelerator dosimetry checks including: beam output for varying dose rate and gating, dynamic wedges output factors, and electron energy (R_{50}). These measurements are frequently completed using a Farmer-type ion chamber in water (FCW). Ion chamber arrays are capable of performing dosimetric measurement with the proper corrections implemented (i.e. array normalization, temperature and pressure, dose calibration). This work reports on our clinical experience using an ion chamber array, in combination with energy wedges and a web-based QA platform, for monthly beam constancy QA in comparison to an ion chamber in water technique.

SPECIFIC AIM

To investigate the accuracy and stability of an ion chamber array, used in conjunction with a web-based QA platform, to perform monthly linear accelerator dosimetric QA relative to traditional ion chamber in water measurements.

METHODS

- SNC IC PROFILER with Quad Wedges (ICP) (Sun Nuclear Corp. Melbourne, FL) was used in conjunction with SNC Routine, a web-based QA system, to measure monthly beam quality and output across six Varian Truebeams over the course of 18 months.
- Traditional Farmer ion chamber measurements in water (FCW) were taken at calibration (d_{10cm} and d_{ref}) and energy check depths (d_{20cm} and $d_{50\%}$ for photons and electrons, respectively) during the same measurement session and manually recorded in SNC Routine.
- Beam output and energy measurements for both techniques were extracted via SQL query from the SNC Routine database in addition to the session measurement times.
- All machines were equipped with four photon energies (6X, 6X-FFF,10X-FFF,15X), four machines were also equipped with five electron energies (6E,9E,12E,16E,20E).
- Photon and electron beam energy checks using FCW were converted to PDD10 and R50 by dividing clinically measured PDD_{20}/PDD_{10} and dose gradient at R50 [%/mm] for each energy.
- Sessions prolonged due to output change or downtime events were excluded in measurement time analysis.

RESULTS

Beam Output Constancy

Both systems showed similar bias and variation in output measurement, 0.3% +/- 0.6% and 0.4% +/- 0.5% for ICP and FCW, respectively. Energy and session matched output differences between systems were normally distributed with a bias of 0.1% +/- 0.7% and interquartile range of of 0.78% across all energies as both techniques exhibited similar dispersion. All measurement values were well-bounded within our institutional 2% output tolerance for monthly constancy.

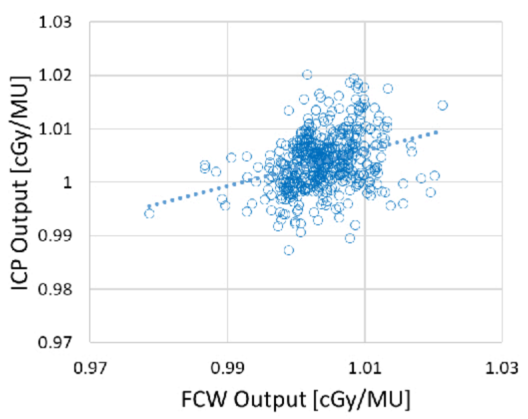

Figure 1 – Scatter plot of ICP vs FCW across all energies and machines. Values are well bounded within clinical 2% tolerance.

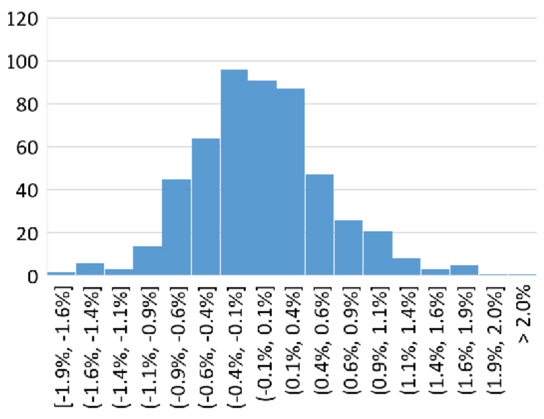

Figure 2 – An output difference histogram contrasting both techniques. Normally distributed and centered around zero. Interquartile range = 0.78%, Stdev = 0.70%.

Beam Energy Constancy

ICP energy measurements exhibited less bias from deviation and less measurement variability across all machines and energies, with the exception of 20E where FCW had less variation. R50 and D10 beam quality measurements for ICP and FCW yielded RMSE values of 0.07 and 0.19 mm across all electrons and 0.14 and 0.52% across all photons, respectively. Comparing measurement techniques from the same session showed a centered, but slightly skewed distribution.

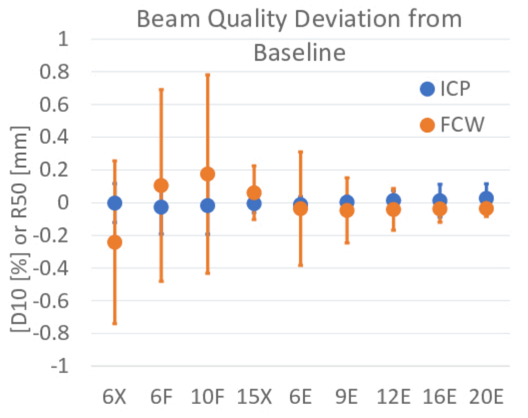

Figure 3 – Deviation of measured energy from baseline across all energies and machines using the two beam constancy measurement techniques.

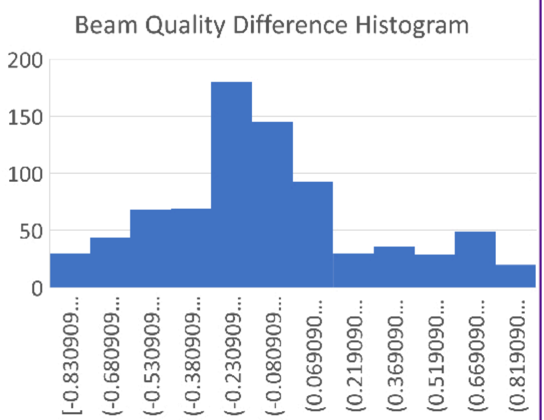

Figure 4 – Histogram of the differences between techniques from their baselines taken during the same measurement session across all machines and energies.

Monthly QA Measurement Time

Over 100 photon and 70 electron paired measurements were performed. Setup and breakdown times are experienced physicist estimates and measurement time from SNC Routine database timestamps. Measurement time was reduced by more than half using ICP. Standard deviations are indicated within parenthesis.

Table 1: Time required for FCW and IC PROFILER measurements

	Ion Chamber in Water (FCW)		IC PROFILER with Quad Wedges	
Task	Photon (min)	Electron (min)	Photon (min)	Electron (min)
Device Setup	~20	~2	~5	~2
Measurement	20 (11)	19 (13)	9 (9)	4 (3)
Breakdown	~10	NA	~5	NA
Subtotal	50 (11)	21 (13)	19 (9)	6 (3)
Total	71 (17)		25 (10)	

DISCUSSION

- Over 700 paired FCW and ICP measurements were performed in 100+ photon and 70+ electron measurement sessions over 18 months on 6 linacs using 9 energies.
- ICP output measurements showed similar bias and variation to traditional FCW relative to baseline. Output for both techniques trended together IQR and standard deviations within 1%.
- Energy constancy measurements showed ICP provided less variation in comparison to FCW for photons and electrons, which is most likely attributed to simplified measurement setup and consistency.
- Efficiency measures showed that ICP measurement sessions were completed in approximately 25 minutes as opposed to 75 for FCW.
- Incorporating output and energy checks into monthly profile constancy checks already being taken reduces the total number of measurements without loss of QA fidelity in the machine QA program.

CONCLUSIONS

- A properly baselined and implemented IC PROFILER and SNC Routine system provides similar output measurement, more consistent beam quality, and improved efficiency in comparison to a Farmer chamber in water technique.

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