Significant Differences in Small-Field Output Factors Measured with Various Dosimeters

and Small Field Output Correction Factors for IBA Razor Nano Chamber

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INTRODUCTION

With the advent of IMRT and SBRT radiation therapy techniques, the importance of accurately and correctly measuring small field dosimetric data, including profiles and output factors, during commissioning and beam modelling in a treatment planning system cannot be emphasized enough. Multiple reports spanning almost two decades by the IROC group, with data from hundreds of institutions and LINACs, have attested to a few key findings: that patient-specific IMRT QA pass rates are not indicative for passing of IROC credentialing (a robust metric for an institution to assess their radiation therapy outcome), and repeatedly that one of the major causes for failure has been poor measurement of output factors in small field dosimetry [1]. Small fields, unlike their larger counterparts, present separate challenges, namely: "the steep gradient of the radiation field, volume averaging effect, lack of charged particle equilibrium, partial occlusion of the radiation source, beam alignment," and inability to use a reference dosimeter [2]. Dosimetry protocols have been developed, such as the IAEA TRS-483, which provide guidelines for small field dosimetry, one of which is the application of output correction factors for various suitable dosimeters [3]. However, no major body of physics currently provides output factors for the IBA Razor Nano Chamber (RNC), the smallest commercially-available ion chamber. Independent measurements have been performed and exist in the literature for the RNC, but either they do not go as low as 0.5x0.5 cm^2, explore specifically some effects present for small fields, or exist but are not plentiful or robust enough in quantity [4-6].

AIM

The aim of this study is to obtain output correction factors for the IBA RNC for small fields by comparing them to EBT3 film and other dosimeters and to help fill in the gap of independent evaluations of small field correction factors for the RNC.

METHOD

IBA CC13, IBA CC04, IBA CC01, IBA RNC, a mini Si-diode Scanditronix-Wellhöfer SFD (Stereotactic Field Detector), and EBT3 Gafchromic Film were irradiated using an Elekta VersaHD Agility Linear Accelerator. For all but the film, a large water tank was used with a 6 MV beam to deliver radiation at 10 cm depth and 100 SSD for various square field sizes (10, 4, 3, 2, 1, 0.5 cm wide). A +300 V bias voltage was applied to the ion chambers (and 0 V for the diode) and measurements were taken at the effective point of measurement of each dosimeter. The film was irradiated under similar conditions using solid water. The film (both the calibration and the measurements) was read 48 hours later with an Epson 10000XL scanner. Output factors were obtained relative to the 10x10 cm^2 field. Output correction factors from TRS-483 for small fields were applied for dosimeters included in the report.

RESULTS

The output factors obtained for field sizes down to 2x2 cm^2 agreed within 1% for the IBA CC13, CC04, CC01, and RNC chambers. For the 1x1 cm^2 field size, the CC01 and RNC agreed to within 1% as well, but there was about a 3% discrepancy between the two for the 0.5x0.5 cm^2 field size. This can be observed from Figure 1, where the top three lines (larger field sizes) are consistent for the first four detectors (or in Figure 2, where the lines representing the four detectors overlap for larger field sizes). The EBT3 Gafchromic film did not agree very well with the ion chambers, and had a propensity to underestimate the output factor for larger field sizes and overestimate for smaller field sizes. The absolute dose to the 10x10 cm^2 film was within 0.6% of the expected dose (calculated using PDD data for the particular LINAC). On the other hand, the SFD diode, intended to be used with small fields, underestimated the dose, relative to the other dosimeters, for all field sizes except the 0.5x0.5 cm^2. The results are displayed in Figure 1 and Figure 2 (separately with respect to dosimeter and with respect to field size), as well as in Table 2.

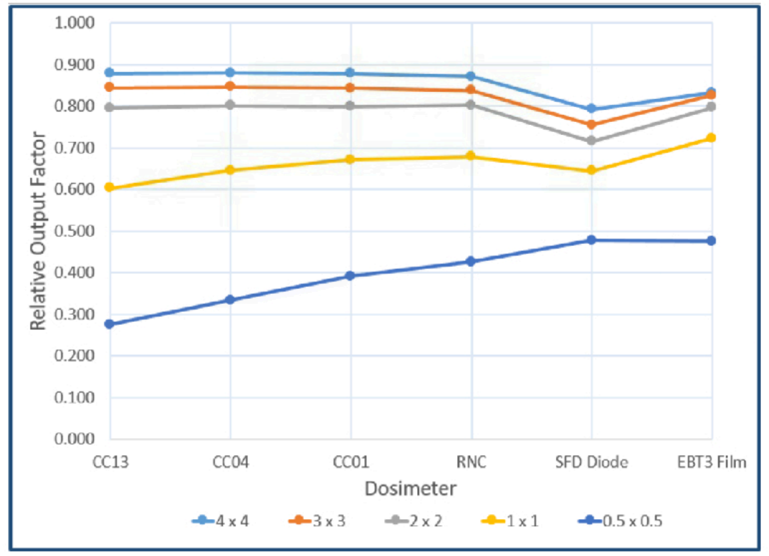

Figure 1. Output Factors for each field size with respect to various dosimeters

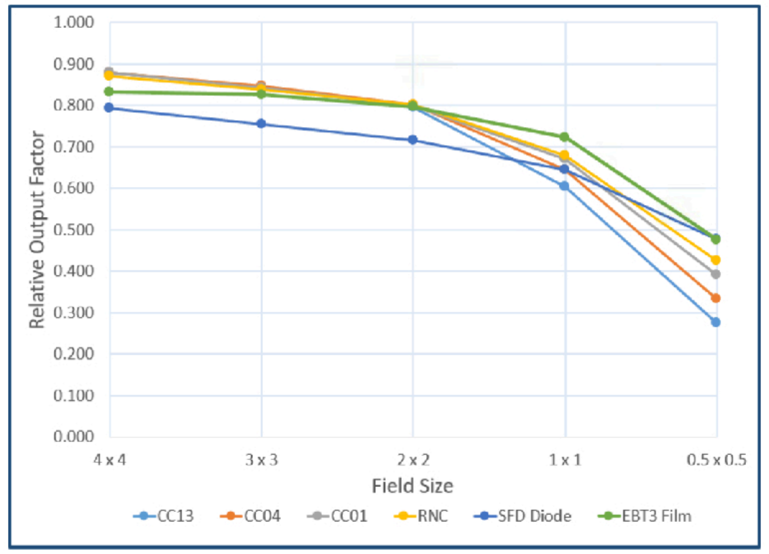

Figure 2. Output Factors from various dosimeters with respect to Field Size

Table 2. Output Factors Determined from Measurements

Output Factors for Various Dosimeters					
	Field Size				
Dosimeter	4 x 4	3 x 3	2 x 2	1 x 1	0.5 x 0.5
CC13	0.878	0.844	0.796	0.603	0.275
CC04	0.880	0.846	0.801	0.645	0.333
CC01	0.878	0.842	0.798	0.671	0.391
RNC	0.871	0.837	0.802	0.679	0.425
SFD Diode	0.792	0.755	0.715	0.644	0.477
EBT3 Film	0.832	0.826	0.796	0.723	0.475

DISCUSSION

The fact that four dosimeters—the CC13, CC04, CC01, and Razor Nano Chamber—agree for field sizes of 2x2 cm^2 and larger gives us confidence in the accuracy of our measurements. For field sizes smaller than that, the disagreement of the larger CC13 and CC04 can be explained by volume averaging effects, and the fact that the field sizes are comparable or smaller than the radii of the chambers. However, even for the smallest field sizes, the CC01 and RNC are in good agreement. For this reason, we suggest that the "ground truth" measurement for field sizes of 2x2 cm^2 or larger be taken confidently as the average of the CC13, CC04, and CC01 chambers, and that the CC01 measurements be taken for the smaller field sizes. By normalizing the RNC dose to these values, we can obtain output correction factors for the RNC for small field sizes as such:

Table 1. Recommended Output Correction Factors for IBA RNC

Field size (sq. cm)	4 x 4	3 x 3	2 x 2	1 x 1	0.5 x 0.5
Output Correction Factor	1.009	1.009	0.995	0.989	0.919

We were initially expecting that the film would serve as our "ground truth", to which we could normalize our RNC measurements to obtain the output correction factors. However, the film measurements were performed twice, and each time gave us sporadic and noisy results that were dissimilar to the other dosimeters. We posit that the discrepancy in our film is attributable to the susceptibility of film to both setup and scanning errors. Since we are confident in our performance of the film measurements and readout (as it was performed meticulously twice, and our dose for the 10x10 cm^2 field size was within 0.6%), we posit that our scanning resolution (200 dpi) was not adequate for small field dosimetry, producing noisy and inaccurate results with high variance [7]. Despite our protocol for film being lacking, the consistent data we obtained from the other dosimeters (ion chambers) allows us to confidently suggest output correction factors for the RNC. Finally, as far as the overestimation from our diode measurements, we posit that some of the disadvantages of diodes came into play, namely the energy dependence and material of the detector [8] [9], that we did not expect at the time of measurement. To explore whether our measurements are attributable to this factor, further measurements need to be taken, such as at higher energies and also using other diode detectors.

CONCLUSIONS

Small field dosimetry presents additional challenges to obtaining accurate data for LINAC modeling and commissioning of a treatment planning system. Because of this, we strongly recommend extra diligence and the use of multiple dosimeters in determination of small field output factors to corroborate the measurements. We also posit that when using the IBA RNC, small field output correction factors from Table 1 can be used.

Further work needs to be performed, comparing film and diode as well as other chambers, utilizing proper protocols, to corroborate our data as well as the shortcomings of this study (mainly the discrepancy in our film and diode measurements). We introduce our findings and results into the pool of studies for small field output correction factors, though cautiously so for field sizes smaller than 2x2 cm^2.

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