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An analysis of TG-51 electron beam calibration correction factor uncertainty.

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Purpose/Objective: Unlike photon beams which have made great strides in standardizing X-ray energies, electron beams have not been standardized and there is much more variability between beams of the same nominal energy. The purpose of this study is to analyze the uncertainty of the TG-51 electron beam calibration correction factors for farmer type ion chambers currently used by institutions in the radiotherapy community site visited by IROC Houston.

Material/Methods: The IROC Houston' physicists, as a part of IROC Houston's QA program, perform onsite dosimetry review visits to institutions participating in NCI's National Clinical Trial Network protocols. One of the components of the site visit is to perform comprehensive reviews of the electron beam calibrations at each of the institution site visited. The TG-51 calibration factors/data were collected for 1174 and 197 distinct electron beams from modern Varian and Elekta accelerators, respectively from 181 institutions visited by IROC Houston physicists. The institutions electron beam calibration TG-51 data that was collected and analyzed included ion chamber make and model, nominal electron energy, $N_{D,w}$, I_{50}, R_{50}, k'_{R50}, d_{ref}, P_{gr} and %dd(d_{ref}). k'_{R50} data for parallel plate chambers were excluded from the analysis. For each nominal electron energy, the mean value, standard deviation and range for each TG-51 parameter were calculated and tabulated for the Varian and Elekta machines. In addition. the range in k'_{R50} that would result from the range of R_{50}'s for each nominal energy are also tabulated.

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Results: Unlike photon beams, electron nominal energy is a poor indicator of the actual energy as evidenced by the range of R_{50} values for each electron beam energy (6 – 22 MeV). The large range in R_{50} values resulted k'_{R50} values with a small standard deviation but large range between maximum value used and minimum value used for a specific Varian nominal energy (0.001 - 0.029).

	I_{50}			R_{50}			d_{ref}			$k'R_{50}$			P_{gr} (0.6 cc farmer only)			FDD-dref			range in $k'R_{50}$ based on range of R_{50}
Nom E	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	
6	2.34	0.09	0.6	2.34	0.09	0.7	1.31	0.06	0.4	1.029	0.004	0.029	1.001	0.008	0.051	0.998	0.005	0.049	0.013
9	3.54	0.10	0.8	3.58	0.10	0.8	2.05	0.06	0.4	1.018	0.003	0.026	1.000	0.004	0.023	0.999	0.003	0.020	0.010
12	4.94	0.12	0.9	5.02	0.12	1.0	2.91	0.07	0.6	1.009	0.002	0.023	0.998	0.002	0.009	0.999	0.002	0.014	0.008
15-16	6.46	0.17	1.0	6.59	0.18	1.0	3.86	0.11	0.6	1.003	0.003	0.027	0.995	0.003	0.019	0.993	0.006	0.039	0.004
18	7.46	0.10	0.4	7.61	0.10	0.4	4.46	0.06	0.3	0.999	0.000	0.001	0.994	0.003	0.012	0.978	0.010	0.057	0.001
20	8.19	0.13	0.9	8.37	0.14	0.9	4.92	0.08	0.5	0.998	0.001	0.005	0.994	0.003	0.016	0.961	0.014	0.088	0.003
22	8.72	0.14	0.5	8.91	0.14	0.5	5.25	0.08	0.3	0.998	0.003	0.012	0.992	0.001	0.004	0.948	0.008	0.025	0.004

Table 1. Varian TG-51 electron beam data.

	I_{50}			R_{50}			d_{ref}			$k'R_{50}$			P_{gr} (0.6 cc farmer only)			FDD-dref			range in $k'R_{50}$ based on range of R_{50}
Nom E	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	mean	stdev	range	
6	2.50	0.14	0.6	2.52	0.13	0.6	1.41	0.09	0.4	1.027	0.003	0.014	0.993	0.008	0.027	0.997	0.002	0.007	0.010
8	3.31	0.17	0.6	3.34	0.17	0.6	1.89	0.14	0.6	1.019	0.001	0.003	0.995	0.002	0.005	0.997	0.001	0.004	0.009
9	3.66	0.15	0.6	3.70	0.16	0.7	2.14	0.10	0.4	1.016	0.001	0.004	0.995	0.004	0.012	0.997	0.003	0.011	0.009
10	4.14	0.27	1.1	4.17	0.26	1.1	2.39	0.18	0.8	1.013	0.001	0.004	0.996	0.001	0.003	0.997	0.002	0.006	0.010
12	4.86	0.20	0.8	4.91	0.21	1.0	2.85	0.14	0.6	1.011	0.004	0.014	0.995	0.003	0.010	0.995	0.003	0.012	0.008
15	6.06	0.26	1.0	6.15	0.27	1.1	3.54	0.28	1.3	1.004	0.001	0.005	0.993	0.004	0.012	0.987	0.008	0.032	0.007
18	7.09	0.23	1.0	7.24	0.22	0.9	4.17	0.35	1.5	1.000	0.001	0.002	0.994	0.002	0.010	0.985	0.005	0.018	0.003
20	7.94	0.17	0.6	8.11	0.17	0.6	4.77	0.10	0.4	0.998	0.000	0.001	0.997	0.004	0.009	0.967	0.007	0.021	0.002
22	8.78	0.21	0.5	8.97	0.22	0.5	5.28	0.13	0.3	0.996	0.001	0.001	0.993	0.003	0.005	0.953	0.007	0.014	0.003

Table 2. Elekta TG-51 electron beam data.

Varian data showed more variability in k'_{R50} values than the Elekta data (0.001 - 0.014). Using the observed range of R_{50} values, the maximum spread in k'_{R50} values was determined by IROC Houston and compared to the spread of k'_{R50} values used in the community. For Elekta linacs the spreads were equivalent, but for Varian energies (6 - 16 MeV), the community spread was 2 - 6 times larger. Community P_{gr} values had a much larger range of values for 6 and 9 MeV values than predicted. The range in Varian %dd(d_{ref}) used by the community for each energy was large, especially for the lower energies (1.4 - 4.9%) where it should have been very near unity.

	$N_{D,w}$			
Make & Model	Mean	Std. Deviation	Range	Count
Exradin A12/A19	4.915	0.147	0.851	55
NEL 2571	4.557	0.025	0.057	7
PTW Farmer	5.353	0.083	0.573	88
PTW Markus	9.551	0.300	1.022	11
PTW Roos	8.477	0.094	0.297	10
Wellhoffer Graphite Farmer	4.829	0.039	0.080	4

Table 3. Ion chamber $N_{D,w}$ data used to calibrate electron beams. Exradin, PTW Roos and PTW farmer chambers showed the largest spread (11 - 17%) in $N_{D,w}$ values.

Conclusion: While the vast majority of electron beam TG-51 calibration correction factors used are accurate, there is a surprising spread in some of the values used throughout the radiotherapy community. This variability makes it very difficult to derive "standard" or "Golden" electron beam data.