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INNOVATIVE ONCOLOGY SOLUTIONS

WATER EQUIVALENCE AND CLINICAL DOSIMETRY FOR CLEARSIGHT BOLUS

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ABSTRACT

This report includes physical and dosimetric characteristics of the Clearsight Bolus. In summary:

- In the range of clinical radiotherapy (0.1 to 100MeV) the ratio of effective atomic number of Clearsight Bolus and water is constant at 0.761 to within ±0.02.
- Physical (mass) density ranges between 0.848-0.857 g/cm3 depending on the type and measurement technique, which is compensated by slightly increased thickness.
- Surface dose underneath Clearsight Bolus agrees with a separate water equivalent commercial bolus product to within (mean±standard deviation) -0.9%±2.3% for photons and -0.4%±1.8% for electrons.
- There is negligible change to photon and electron depth dose curves when the equivalent thickness of water is replaced by the Clearsight Bolus.

DETAILED REPORT

INTRODUCTION:

The Clearsight Bolus (Clearsight RT LLC) is a highly transparent polymer gel designed to be used as a radiotherapy bolus material. Due to the density being slightly less than water they are manufactured in sheets that are slightly thicker than the intended water equivalent thickness, as detailed in Table 1. Due to unique challenges in manufacturing thinner sheets, the 3mm water equivalent sheets have slightly different makeup from the thicker (5mm+) sheets. Thus, many results are reported separately for 3mm sheets.

EFFECTIVE ATOMIC NUMBER:

The effective atomic number was calculated for a polymeric gel prototype of the Clearsight Bolus. For this prototype, the atomic mass fraction was 15.1% Hydrogen and 84.9% Carbon. From this atomic mass fraction, the effective atomic number was calculated using software developed by Taylor *et al.* [1]. The resulting effective atomic number is shown in Figure 1 for energies ranging from 0.01 to 1000MeV. As shown in the Figure, the effective atomic number is lower than water, but proportional. In the range of clinical radiotherapy (0.1 to 100MeV), **the ratio of the bolus and water effective atomic numbers is constant at 0.761 to within ±0.02**.

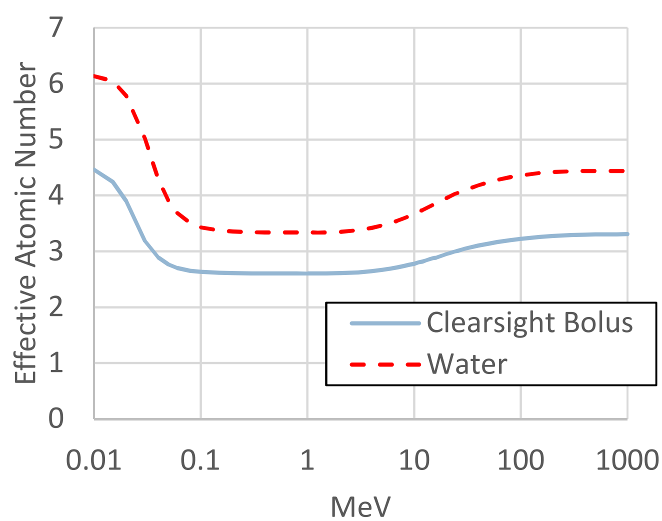

Figure 1: Effective atomic number vs. energy

MASS DENSITY AND ELECTRON DENSITY:

Physical and electron density was calculated from the Houndsfield Units from a multislice diagnostic CT scanner (Discovery CT590 RT, GE Medical Systems). Four bolus samples were inserted into select cavities of a CT Electron Density Phantom, also included were six inserts of known mass and electron density: these were equivalent to lung (inhale), lung (exhale), adipose, water, breast, and liver. A CT image was acquired (120kVp, 173mAs, 0.25cm slice thickness), and the average Hounsfield Units in the resulting CT image were quantified for all inserts at the central slice. A linear fit was then used to equate the mean Houndsfield Unit of the bolus to known mass density and electron density. In addition, the density was calculated as the ratio of the measured mass and volume. Sample mass was measured with an Ohaus Valor ABS Compact Precision Scale with 1g resolution. Sample volume was measured as the volume of water displaced in a 250ml graduated cylinder beaker. The measured mass density is given in Table 1.

Table 1: Measured mass density and electron density

bolus	mass density (g/cm^3)	diagnostic CT mass density (g/cm^3)	diagnostic CT electron density (ratio to water)	manufactured thickness (cm)
0.3cm water equivalent	0.848 ± 0.008	0.852 ± 0.003	0.839 ± 0.007	0.35
0.5cm water equivalent	0.853 ± 0.002	0.857 ± 0.004	0.844 ± 0.007	0.57
1.0cm water equivalent	0.853 ± 0.002	0.857 ± 0.004	0.844 ± 0.007	1.15
2.0cm water equivalent	0.853 ± 0.002	0.857 ± 0.004	0.844 ± 0.007	2.30

SURFACE DOSE BELOW CLEARSIGHT BOLUS:

Surface dose was measured below commercial sheets of Clearsight Bolus and compared to the surface dose below another water equivalent commercial bolus product (Bolus with Skin, CIVCO Medical Solutions, Coralville, Iowa) for the same water equivalent thickness. Optical Stimulated Luminescence Dosimeters (OSLDs) were placed at central axis on solid water backscattering material with 100cm distance from source to surface; bolus was then placed on the solid water. Surface dose was measured for photons (6 & 15MV) with a $10x10cm^2$ field size and incident beam angles of 0° and 30°. Surface dose was also measured for electrons (6, 9, 12, 16, and 20MeV) with a $15x15cm^2$ applicator with a 0° incident beam angle.

The difference in surface dose for the Clearsight Bolus compared to the separate commercial bolus is given Tables 2 and 3. **The overall difference was -0.9%±2.3% for photons and -0.4%±1.8% for electrons.**

Table 2: Photon surface dose difference from commercial bolus.

equiv. thickness (mm)	photon energy (MV)	angle (deg)	difference
3	6	0	2.3%
3	15	0	-0.6%
3	6	30	-3.9%
3	15	30	-5.6%
5	6	0	1.7%
5	15	0	-0.5%
5	6	30	0.8%
5	15	30	-1.9%
10	6	0	-1.1%
10	15	0	0.7%
10	6	30	-0.8%
10	15	30	-2.0%
3			-2.0%±3.5%
5			0.0%±1.6%
10			-0.8%±1.1%
	6		-0.2%±2.3%
	15		-1.7%±2.2%
		0	0.4%±1.4%
		30	-2.2%±2.3%
overall			**-0.9%±2.3%**

DEPTH DOSE BELOW CLEARSIGHT BOLUS:

The electron depth dose and range was measured below the Clearsight Bolus and compared to that of water. This measurement was made using an electron diode (EFD 3G-pSi, IBA dosimetry) in water. The depth dose curve was first measured in water with a source to surface distance (SSD) of 100cm. The measurement was then repeated with the Clearsight Bolus floating on the surface; in this case the SSD was set to be 100cm at the water surface surrounding the bolus. Thus the SSD at the bolus was 100cm minus the difference between the water equivalent thickness and physical thickness of the Clearsight Bolus. For instance, the SSD for the 1cm bolus was 100cm – (1.15cm – 1.0cm) = 99.85cm. The depth dose curves were measured for 6 and 15MV photons with 10x10cm^2 field size, and for 6-20 MeV electrons with a 15x15cm applicator.

Photon depth dose is shown in Figure 2, and resulting PDD_{10cm} is given in Table 4. For 6MV photons, the percent depth dose at 10cm depth (PDD10cm) was 66.9% in water, compared to 66.4%±0.1% under the bolus. The PDD10cm values in Table 4 assume the nominal water equivalent thickness of each bolus. **Figure 2 and Table 4 indicate that the nominal water equivalent thickness of each bolus can be used with negligible change to photon depth dose.**

Table 4: Photon percent depth dose in water under bolus assuming nominal water equivalent thickness.

	PDD_{10cm}	
bolus	6MV	15MV
water only	66.9	76.6
0.3cm equivalent	66.6	76.3
0.5cm equivalent	66.3	76.3
1.0cm equivalent	66.4	76.7
difference	0.4±0.1	0.1±0.2

Table 3: Electron surface dose difference from commercial bolus.

thickness (mm)	energy (MeV)	% difference	
		mean	stdev
3	6	0.9%	
3	9	-1.3%	
3	12	-0.2%	
3	16	-0.5%	
3	20	0.0%	
5	6	1.1%	
5	9	-0.8%	
5	12	-0.8%	
5	16	0.4%	
5	20	-1.1%	
10	6	-4.3%	
10	9	-2.6%	
10	12	0.4%	
10	16	3.6%	
10	20	-0.2%	
3		-0.2%	0.8%
5		-0.2%	0.9%
10		-0.6%	3.0%
	6	-0.8%	3.1%
	9	-1.6%	0.9%
	12	-0.2%	0.6%
	16	1.2%	2.2%
	20	-0.4%	0.6%
overall		**-0.4%**	**1.8%**

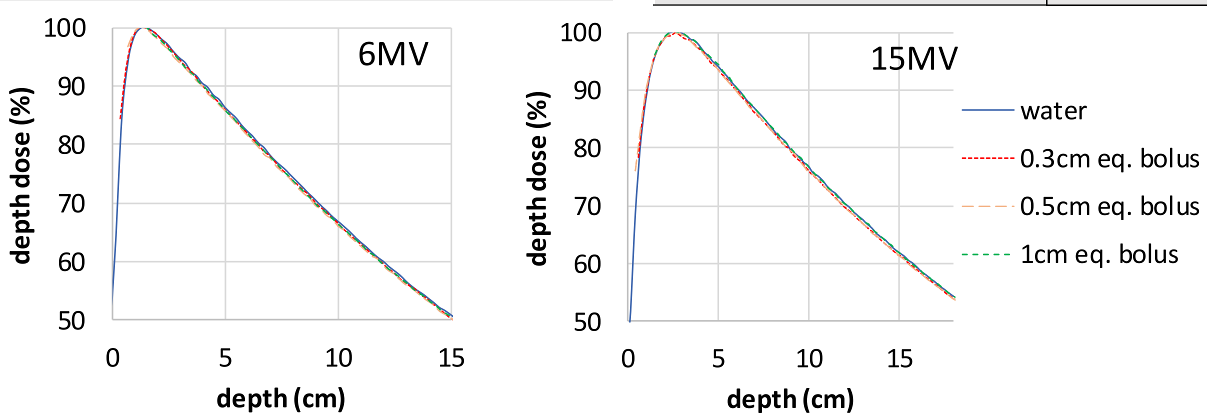

Figure 2: Photon depth dose in water under each thickness of Clearsight Bolus.

The measured depth dose curves for electrons are shown in Figure 3. Table 5 compares the depth at which the absorbed-dose falls to 50% of the maximum dose ($R_{50\%}$). The values of $R_{50\%}$ in Table 5 assume the nominal water equivalent thickness of each bolus. **Figure 3 and Table 4 indicate that the nominal water equivalent thickness of each bolus can be used with negligible change to electron depth dose.**

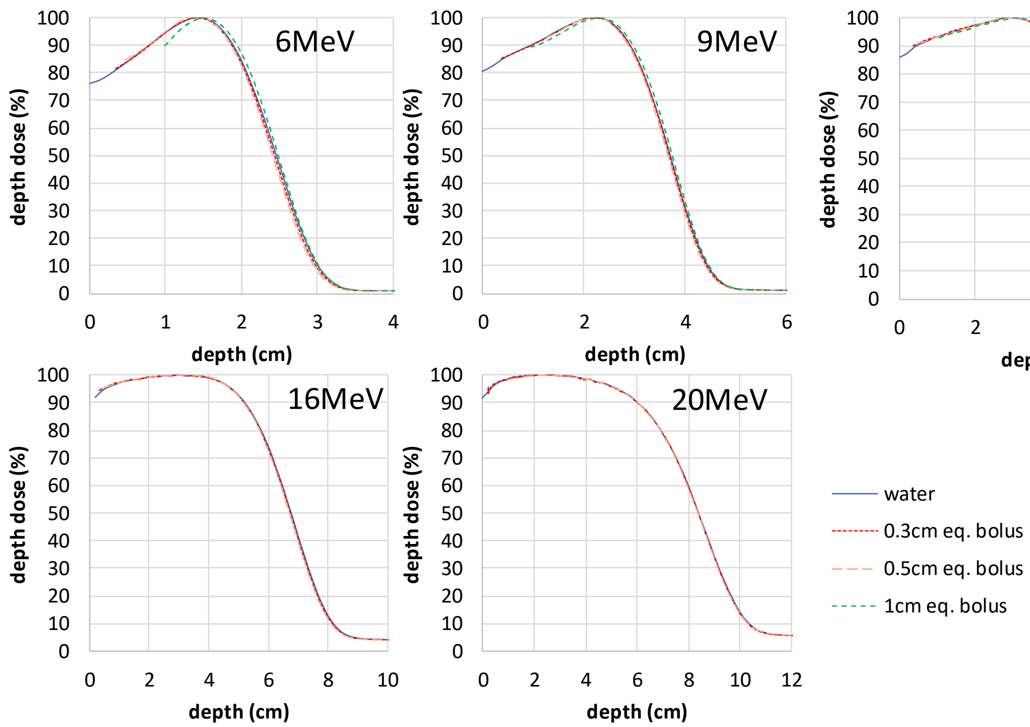

Figure 3: Electron depth dose in water under each thickness of Clearsight Bolus.

Table 5: Electron beam $R_{50\%}$ in water under bolus assuming nominal water equivalent thickness. The difference from water indicates negligible change to $R_{50\%}$.

			$R_{50\%}$ (cm)		
bolus	6MeV	9MeV	12MeV	16MeV	20MeV
water only	2.46	3.69	5.12	6.75	8.41
0.3cm equivalent	2.44	3.68	5.11	6.74	8.40
0.5cm equivalent	2.42	3.65	5.09	6.71	8.38
1.0cm equivalent	2.49	3.73	5.16	6.79	8.46
Difference from water	0.01±0.04	0.00±0.04	0.00±0.04	0.00±0.04	0.00±0.04

REFERENCES

[1] Taylor M L, Smith R L, Dossing F and Franich R D 2012 Robust calculation of effective atomic numbers: The Auto- Z_{eff} software *Med. Phys.* **39** 1769–78