

VERSION 3-2020

3/27/2020



# WATER EQUIVALENCE AND CLINICAL DOSIMETRY FOR CLEARSIGHT BOLUS

PREPARED BY: CLEARSIGHT RT LLC

PO BOX 62612

DURHAM NC 27715



---

## 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  $\pm 0.02$ .
- Measured physical (mass) density ranges between 0.851-0.867 g/cm<sup>3</sup> depending on the 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 $\pm$ standard deviation)  $-0.9\%\pm 2.3\%$  for photons and  $-0.4\%\pm 1.8\%$  for electrons.
- There is negligible change to photon and electron depth dose curves when the equivalent thickness of water at the surface is replaced by the Clearsight Bolus.

---

## DETAILED REPORT

### INTRODUCTION:

The Clearsight Bolus (Clearsight RT LLC) is a highly transparent polymer gel designed 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  $\pm 0.02$ .**

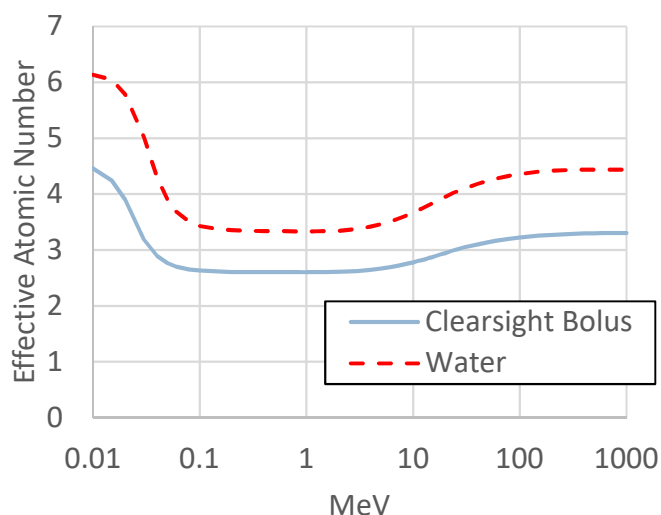


Figure 1: Effective atomic number vs. energy

### MASS DENSITY AND ELECTRON DENSITY:

Mass density was measured using the Archimedean method from two independent laboratories (in house and NSL Analytical, Cleveland OH), as well as by helium pycnometry (Intertek USA Inc., Boston MA). For the in house measurement, sample mass was measured with an Ohaus Valor ABS Compact Precision Scale with 1g resolution. Sample volume was measured as volume of water displaced in a 250ml graduated cylinder beaker. In addition, physical and electron density were calculated from Hounsfield Units from a

diagnostic CT (Discovery CT590 RT, GE Medical Systems); bolus samples were inserted into select cavities of a CT Electron Density Phantom along with other inserts of known mass and electron density. A CT image was acquired (120kVp, 173mAs, 0.25cm slice thickness), and average Hounsfield Units were quantified for all inserts at the central slice. Linear and polynomial fits were used to equate the mean Hounsfield Unit of the bolus to known mass density and electron density. The measured mass density is given in Table 1. The electron density (ratio relative to water) was measured to be  $0.847 \pm 0.01$  for the 3mm water equivalent bolus, and  $0.844 \pm 0.01$  for greater thicknesses. Intra- and inter-sheet variability was also measured via diagnostic CT; 95% of variability (including CT image noise) was found to be within  $\pm 1.7\%$  and  $\pm 0.7\%$  for the 3mm water equivalent, and  $\pm 1.2\%$  and  $\pm 0.1\%$  for greater bolus thicknesses, respectively.

**Table 1: Measured mass density and electron density**

bolus	manufactured thickness (cm)	mass density (g/cm <sup>3</sup> )				
		Archimedean		helium		average (all)
		lab 1	lab 2	pycnometry	diagnostic CT	
0.3cm water eq.	0.35	$0.851 \pm 0.01$	0.84	$0.867 \pm 0.0004$	$0.858 \pm 0.010$	<b><math>0.854 \pm 0.01</math></b>
0.5cm water eq.	0.57	$0.853 \pm 0.01$	0.85	$0.862 \pm 0.0002$	$0.855 \pm 0.005$	<b><math>0.855 \pm 0.01</math></b>
1.0cm water eq.	1.15	$0.853 \pm 0.01$	0.85	$0.862 \pm 0.0002$	$0.855 \pm 0.005$	<b><math>0.855 \pm 0.01</math></b>
2.0cm water eq.	2.30	$0.853 \pm 0.01$	0.85	$0.862 \pm 0.0002$	$0.855 \pm 0.005$	<b><math>0.855 \pm 0.01</math></b>

### SURFACE DOSE BELOW CLEARSIGHT BOLUS:

Surface dose was measured below sheets of ClearSight Bolus and compared to 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<sup>2</sup> 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<sup>2</sup> applicator with a 0° incident beam angle.

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

### DEPTH DOSE BELOW CLEARSIGHT BOLUS:

Electron depth dose and range were measured below ClearSight Bolus and compared to that of water using an electron diode (EFD 3G-pSi, IBA dosimetry) in water. The depth dose curve was first measured in

**Table 2: Photon surface dose difference from commercial bolus.**

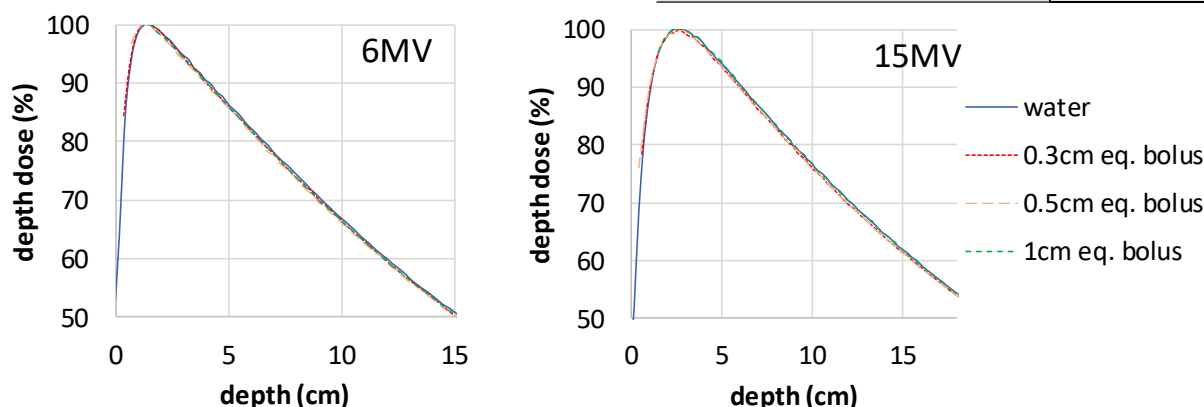
equiv. thickness (mm)	photon energy (MV)	angle (deg)	difference
3	6	0	2.3%
3	15	0	-0.6%
3	6	30	-3.9%
3	15	30	-5.6%
5	6	0	1.7%
5	15	0	-0.5%
5	6	30	0.8%
5	15	30	-1.9%
10	6	0	-1.1%
10	15	0	0.7%
10	6	30	-0.8%
10	15	30	-2.0%
<b>3</b>			<b>-2.0%±3.5%</b>
<b>5</b>			<b>0.0%±1.6%</b>
<b>10</b>			<b>-0.8%±1.1%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

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  $100\text{cm} - (1.15\text{cm} - 1.0\text{cm}) = 99.85\text{cm}$ . The depth dose curves were measured for 6 and 15MV photons with  $10 \times 10\text{cm}^2$  field size, and for 6-20 MeV electrons with a  $15 \times 15\text{cm}$  applicator.

Photon depth dose is shown in Figure 2, and resulting  $\text{PDD}_{10\text{cm}}$  is given in Table 4. For 6MV photons, the percent depth dose at 10cm depth ( $\text{PDD}_{10\text{cm}}$ ) was 66.9% in water, compared to  $66.4\% \pm 0.1\%$  under the bolus. The  $\text{PDD}_{10\text{cm}}$  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.**

bolus	$\text{PDD}_{10\text{cm}}$	
	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	$0.4 \pm 0.1$	$0.1 \pm 0.2$

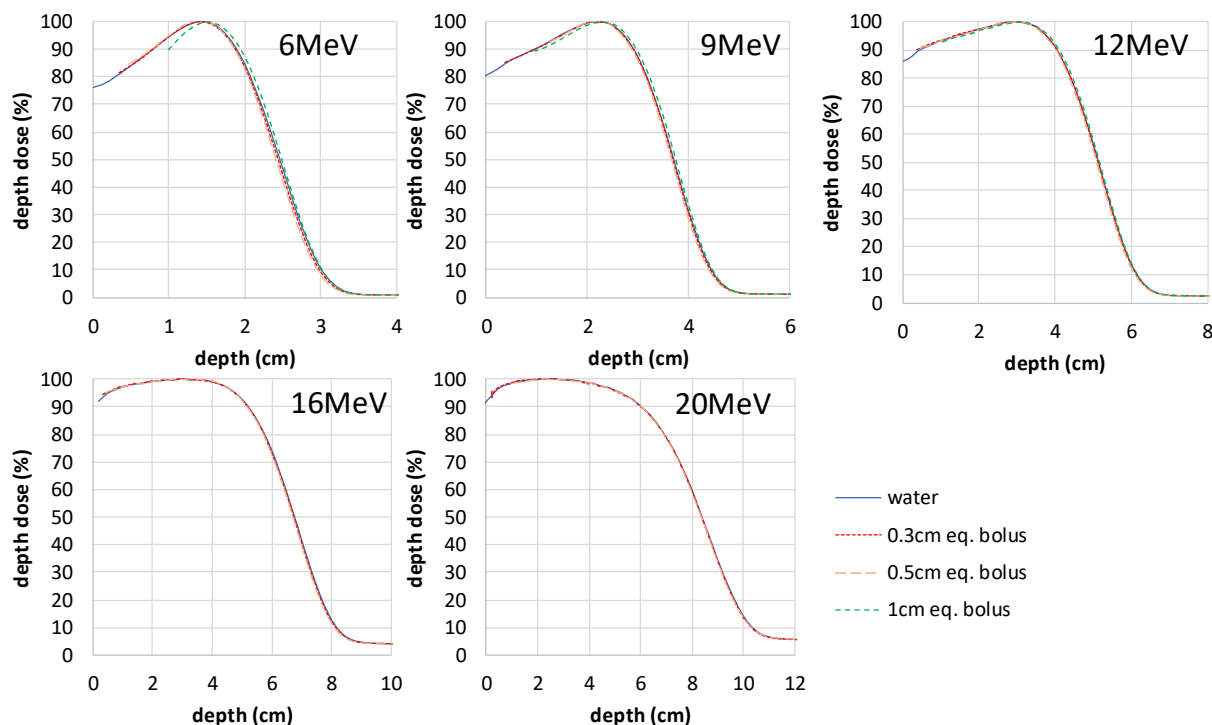


**Figure 2: Photon depth dose in water under each thickness of ClearSight Bolus.**

**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%

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  $R_{50\%}$ .**

bolus	$R_{50\%}$ (cm)				
	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