Klarity AccuCushion™ Headrest Dosimetry Report

Purpose:

This report is to investigate the dosimetric properties of Klarity's AccuCushion™ headrest unit. AccuCushion™ is a headrest cushion that can be molded to a patient's head when heat is applied. Once cooled, the cushion will form to the head and keep its shape for future setups. The product is used for both patient immobilization and comfort. The intended use is for head support for supine-oriented patients, although it can be used for extremity immobilization as well. In order to implement the headrest into the clinical setting, the dosimetric properties need to be analyzed. This was accomplished by scanning the headrest via a CT simulator and analyzing the CT numbers at different locations. This CT study set was exported to the treatment planning system. Any significant perturbation of the depth dose characteristic through the headrest was compared to the treatment planning system. Experiments in this report include analyzing the transmission values of the headrest by taking measurements with an ion chamber and subsequently verifying these values in the treatment planning system. An overall decision was made whether to contour the headrest for every patient if beam transmits through the cushion.

Materials and Specifications:

Klarity AccuCushion™ cushions consist of polystyrene beads and hydraulic urethane resin within the mold. These are surrounded by a 1.6mm thick low-temperature thermoplastic (polycaprolactone) layer with a cotton stockinette cover. Cushions are heated in a convection oven to about 155°F. (68°C.), whereupon they become moldable by hand, and are shaped for their intended use.

Methodology and Results:

Transmission measurements were performed for a new, unmolded headrest as well as a typical head-shaped mold for a patient. Three energies were measured (6 MV, 15 MV, and 6 FFF) on a Varian TrueBeam linear accelerator. Readings were taken with a farmer chamber (PTW 30011) in water equivalent phantom (Solid Water). The transmission was determined by taking the ratio of the readings with and without a headrest in the beam. With the gantry at 0^{o}, 100 MUs were delivered using a 10x10 cm^2 field size at 100 cm SSD to the phantom. The ion chamber was at 5 cm depth with 15 cm backscatter. When placing both the new and molded headrest on the phantom, the new SSD measured 96 cm along the central axis, making the width of the headrests 4 cm.

Figure 2 – Transmission measurement setup for new (left) and molded (right) headrest.

The following values were recorded:

Table 3 – Readings without headrest, 100 cm SSD.

No Headrest			
Reading	**6x**	**6FFF**	**15x**
1	15.29	15.01	16.54
2	15.30	14.98	16.52
3	15.30	14.97	16.52
Average	**15.30**	**14.99**	**16.53**

Table 4 – Readings with unmolded headrest, 96 cm SSD.

New Headrest			
Reading	**6x**	**6FFF**	**15x**
1	15.07	14.71	16.35
2	15.07	14.69	16.35
3	15.06	14.69	16.35
Average	15.07	14.70	16.35
Transmission	**0.985**	**0.981**	**0.989**

Table 5 –Readings with folded headrest, 96 cm SSD.

Folded Headrest			
Reading	**6x**	**6FFF**	**15x**
1	15.10	14.76	16.40
2	15.10	14.73	16.39
3	15.10	14.73	16.39
Average	**15.10**	**14.74**	**16.39**
Transmission	**0.987**	**0.984**	**0.992**

The transmission values for both the new and folded headrest are in good agreement, with the maximum deviation being 0.3% for both 15X and 6FFF.

Verification of the transmission through the headrest was also analyzed using the Eclipse treatment planning system. First, the headrest was scanned in the GE Discovery computed tomography scanner. The head protocol was used for the scanning parameters. Seven points of interest were analyzed to reach an average Houndsfield unit of the headrest. Points one and two represent the material that covers the headrest (polypropylene). Points A through E represent the polystyrene bead and urethane resin mold. These points lie at all four corners and the center of the mold.

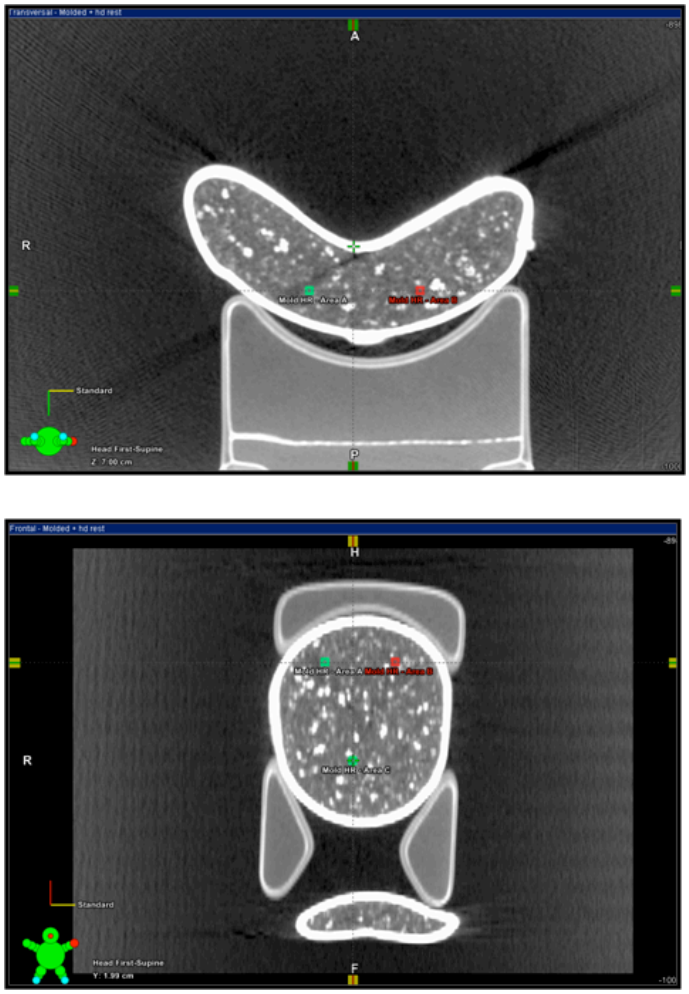

Figure 3 – CT of molded headrest with holder. Points of interest indicated on scan.

Table 6 – Average HU numbers for new cushion, molded headrest, and molded headrest with holder.

New Cushion		Molded		Molded w/ holder	
Point (Border)	HU	Point (Border)	HU	Point (Border)	HU
1	-407	1	-371	1	-429
2	-534	2	-313	2	-679
Average	-471	Average	-342	Average	-554
Area	HU	Area	HU	Area	HU
A	-953	A	-968	A	-974
B	-955	B	-950	B	-970
C	-951	C	-968	C	-968
D	-865	D	-958	D	-950
E	-951	E	-969	E	-968
Average	-935	Average	-963	Average	-966

The cover has a higher density than the beads and resin mold, exhibited by the greater HU number from the CT (difference ~600 HU). However, the thermoplastic and cotton cover is between 3-4 mm thick. Compared to the thickness of the beads and resin mold (~ 3 cm thick), the cover is significantly thinner. Thus, it was not considered in the average HU of the headrest.

Finally, verification of the transmission was performed using the Eclipse treatment planning system. The molded headrest was scanned using a GE CT Lightspeed. The molded headrest with the holder was analyzed, as it represents the clinical setup of most patients. In Eclipse, a square phantom of a uniform 0 HU number was placed directly under the headrest. The same treatment parameters that was used to measure transmission at the TrueBeam were also used in Eclipse: 100 cm SSD to phantom, 10x10 cm^2 field size, 100 MUs. A point of interest was placed 5 cm deep in the phantom to measure the dose on the central axis. In order to determine transmission via Eclipse, heterogeneity corrections were applied with the beam traveling through the headrest. The PDD value was measured at a depth of 5 cm. A PDD value was also measured at 5 cm with an air structure overlaying the headrest (-1000 HU). The ratio of the PDD at 5 cm with and without the headrest for all energies was determined. The table below includes Eclipse transmission values as well as the difference from the delivered transmission values to the treatment planning transmission values:

Table 7 – Transmission values determined by Eclipse and difference to delivered transmission readings.

In Eclipse (PDD)			
	6x	**6FFF**	**15x**
w/ headrest	82.9	81.4	89.2
w/o headrest	83.8	82.7	89.6
Transmission	**0.989**	**0.984**	**0.996**
Diff from readings (%)	**0.212%**	**0.074%**	**0.360%**

The highest difference in readings is from 15X energy, where there is almost a difference 0.4% comparing transmission values. Good agreement in transmission values is established between Eclipse and actual delivery on the TrueBeam.

Conclusions:

Transmission values were high for en face delivery on the AccuCushion™ headrest, never falling below 98% for low and high MV therapy energies. These values were verified with the treatment planning system, where the difference in transmission values was less than 0.4% for 15X. The average CT number for the molded headrest measured around -960.

Surface dose is a concern when implementing this device. As the thickness of cushion increases, the surface also increases. It is suggested that thicknesses of 2 cm or greater should expect an increase of skin surface dose. Thus, with the molded headrest having a thickness around 4 cm, one should be cautious with inflammatory complications when a beam passes through the headrest.

The AccuCushion™ headrest is a convenient immobilization device that takes approximately 10 minutes to cool into a mold for the patient. Due to its relatively low density, the transmission of an MV photon beam is almost unperturbed. No special transmission factor is needed for any beam passing through the headrest. However, there is an increased risk of inflammation due to the thickness of the headrest. Since the thickness is around 4 cm for a typical brain or head and neck patient, it is suggested that a clinician should be cognizant of any complications that may arise with a beam that would pass through the headrest.

Clinical Implementation Recommendations:

- The AccuCushion™ headrest is to be used for head and neck or brain patients that require immobilization with a thermoplastic mask. The headrest can also be used for extremity immobilization (i.e. wrist or ankle) such that the limb can be restrained while allowing for setup reproducibility and comfort to the patient.
- No correction is needed to account for the perturbation of the incident beam on the AccuCushion™ headrest. Given its low overall CT number (~ -950) it is unnecessary to contour the headrest unless the headrest is greater than normal (≤4cm) thickness.
- Inflammation may occur on the skin if the beam passes through the headrest. Given the thickest portion of the headrest when molded is 4 cm, one can expect inflammation to the area of skin in contact with the headrest of an impinging beam. The clinician should be aware of this effect and administer any treatment with caution.

References:

Kitahara et al. “A new mold material for customized patient positioning in radiotherapy. Radiotherapy and Oncology.” Vol. 47:77-79. 1998.