Treatment Couch Modeling via Measured Attenuation Using a Symmetrically Shaped Stereotactic Phantom

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Abstract

Purpose: To implement a simple approach for accurate density modeling of the treatment couch in the treatment planning system.

Methods: The SunNuclear Stereophan and the A26 chamber was used to measure couch attenuation with 6MV and 15MV at three indexing positions (~H4, ~H1, ~F1) along the VARIAN PerfectPitch 6DoF IGRT couch. The Stereophan was setup isocentrically, and the gantry was set to various angles where radiation passes through the couch. Data collected with couch attenuation was subtracted from that without (the Stereophan can extend off the couch-end). This measured data was then compared to Eclipse predicted values. A single Hounsfield unit, for the Eclipse-modeled medium couch, was retroactively determined to minimize the differences between measurements and Eclipse predictions.

Results:

1) The percent difference in attenuation, with and without couch, is energy dependent.
2) Variation in couch thickness exists with respect to lateral position from the center line; this is largely ignored for the modeled couch in Eclipse.
3) If only a single HU and a single preset thickness in Eclipse is used to produce a best-fit density for the entire couch, Eclipse prediction will be slightly under-attenuated at all couch positions except the thickest part (~F1). Using the medium couch and the Varian default -300HU (physical density ~0.723g/cc), the percent attenuation difference is at most 52% from predictions, and 77% of data are within 20%. At -200HU (physical density ~0.831g/cc), the percent attenuation difference is at most 32% from predictions, and 92% of data are within 20%.
4) The Varian default -300HU is a suboptimal value for the Eclipse-modeled thick couch at the F1 couch position, typical for pelvis treatments.

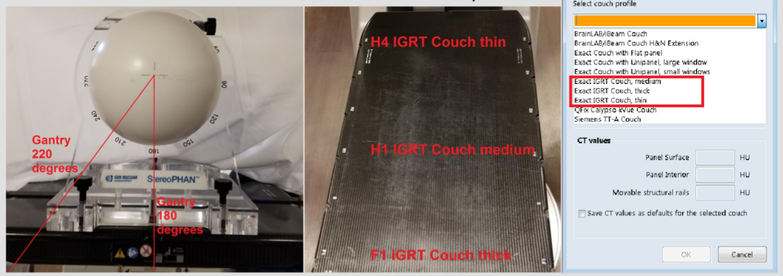
Conclusion: The Stereophan creates a measurement setup, completely independent of machine and measurement device parameters (i.e. machine output, phantom modeling in Eclipse), which can reliably determine treatment couch modeling parameters.

Introduction

Treatment couch modeling in the TPS is important to dosimetric accuracy. The modeled couch in Eclipse allows for variable thickness selection and custom density/HU assignment. The 3 couch model thicknesses: thin, medium, and thick, corresponds to positions H4, H1, and F1, respectively, on the Varian IGRT couch. Qualitative observations indicate couch positions between H4 and H1 is the thinnest and has minimal thickness variation, while positions between H1 and F1 has thickness increases rapidly towards F1. The ideal method of couch modeling in the TPS would be selecting the couch model that relates to couch position during treatment (i.e. couch position for a pelvis treatment is ~F1, and "thick couch" should be used during planning). In practice, however, this is rather cumbersome and prone to error. This experiment seeks to create a one size fits all model for all photon energies and all possible couch longitudinal position. Specifically, it aims to use the medium thickness model in Eclipse and a single HU to best-fits the calculated attenuation values to the measured attenuation values at couch positions H4, H1 and F1.

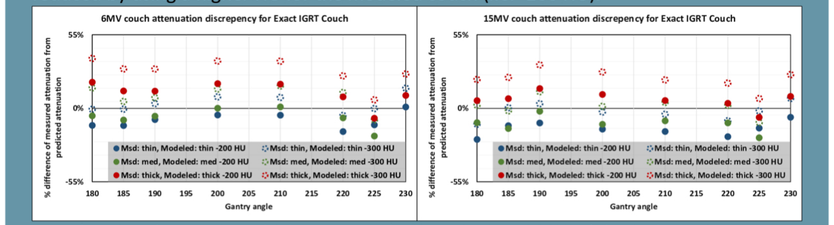
Methods

The measurement setup utilizes the Stereophan, a hemispherical phantom originally intended for QA of stereotactic treatment, to measure attenuation with and without couch using the A26 chamber on 2 photon energies (6X and 15X), at three different couch positions (~H4, ~H1, ~F1). The Stereophan is setup isocentrically, with the gantry at various posterior angles in which radiation would pass through the couch on the entrance side. Measurements with the couch are averaged for angles symmetrical about the midline, then subtracted from that without the couch (since the Stereophan can extend off the end of the couch). Therefore, the results is completely independent of every machine and chamber parameter (i.e. machine output, chamber calibration factor, phantom modeling). The measured attenuation is then compared against calculated attenuation for the 3 corresponding couch models: thin, medium, and thick. To accomplish our intent of only using the medium thickness model in Eclipse, the Hounsfield unit of the CouchSurface contour is determined retroactively so the percent difference between measured vs. calculated couch attenuation is minimal across all data points.

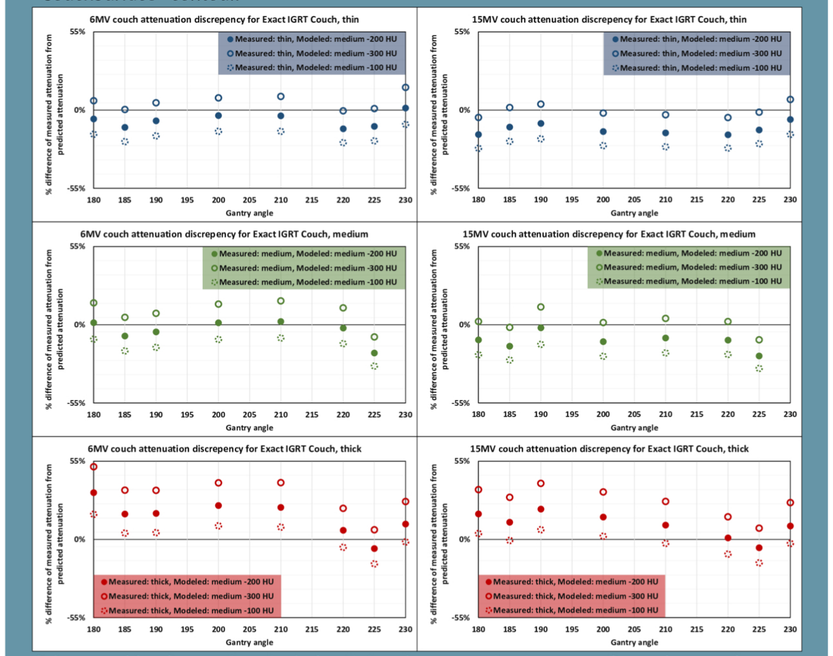


Results

Using the default -300HU provided by Varian, the dotted hollow data series in the plots below shows attenuation is largely correct for the thin and medium model, but is significantly different for the thick model. This worst-case attenuation difference can be reduced by using a higher HU for the modeled couch (i.e. -200 HU).



By only using the medium thickness model and assigning -200HU (physical density ~0.831g/cc), the overall magnitude of percent difference between measured vs. calculated couch attenuation is reduced. In the plots below, positive percentage means the measured attenuation is greater than the Eclipse calculated attenuation. It is evident the overall attenuation difference is minimized (closest to the 0% line) when -200HU is assigned to the "CouchSurface" contour.



Other notable observations include: 1) Couch attenuation is energy dependent, and one HU can't perfectly model all photon energies; 2) Variation in couch thickness exists with respect to lateral position from the center line, this is largely ignored for the modeled couch in Eclipse; 3) The modeled medium thickness couch at -200HU slightly underestimates attenuation at the tip of the couch (~H4), and marginally overestimates at the base (~F1). The average percent difference of attenuation at any given longitudinal couch position is <15%, which in the context of couch attenuation, is an acceptable value.

Conclusion

The Stereophan allows couch attenuation measurement to be independent of all other machine and measurement parameters. In addition, a single couch thickness model with one designated HU can be used to model the Varian IGRT couch in Eclipse, to a high degree of accuracy under all treatment conditions.