

# Investigation of the potential for dosimetric accuracy improvements when utilizing the Gammex 1467 Advanced Electron Density Phantom for CT number conversions of high-density biologic material

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## INTRODUCTION

The accuracy of the CT numbers to relative electron density (CT-RED) curve in the treatment planning system (TPS) is essential to assure accurate heterogeneity corrections. In this study, the dosimetric effect of generating CT-RED calibrations from two commercially available phantoms which handle high-density data points in different ways were compared. One phantom (Gammex 1467) utilized tissue-mimicking materials for data points near bone and the other phantom (Catphan 504) utilized Teflon as a proxy for bony tissue. The goal of the study was to determine if using tissue-mimicking materials results in an appreciable improvement in dose calculation accuracy within and around bony anatomy compared to proxy materials.

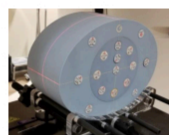
## PURPOSE

To investigate the dosimetric effect of using tissue-mimicking bone-like materials with the Gammex 1467 Advanced Electron Density Phantom versus proxy Teflon materials with the Catphan 504.

## METHOD

First, CT-RED curves were generated for each phantom in the Eclipse 15.5 treatment planning system:

### Phantoms:



### Part I: Impact of CT-RED curves on delivered dose accuracy

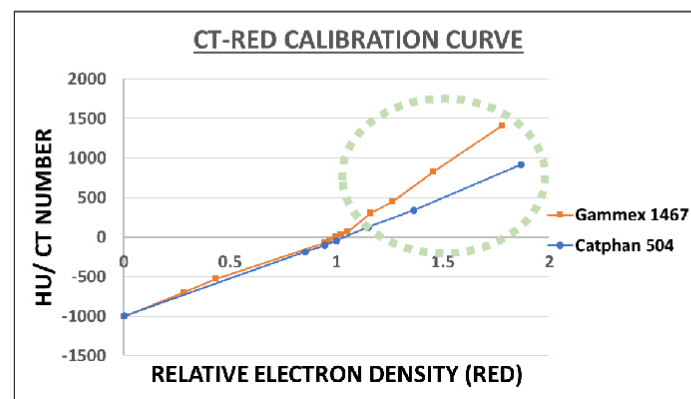
- Create 12 TPS plans irradiating a heterogenous phantom with 2cm of bone-equivalent material for each CT-RED curve
  - Field Size: 5x5, 10x10, 20x20 cm<sup>2</sup>
  - Energy: 6MV, 10MV, 10MVFFF, 15MV
- Deliver the plans to the phantom, measuring absolute dose beyond the bone slab with a Farmer ionization chamber
- Evaluate dosimetric agreement between measurement and TPS as a function of CT-RED curve

### Part II: Impact of CT-RED curves on clinical treatment plans

- Calculate dose on 10 retrospective patient plans treating in or adjacent to bony anatomy
  - Compute using identical field parameters using CT-RED curve generated from each phantom
- Evaluate dosimetric parameters for each plan:
  - D<sub>MEAN</sub> and D<sub>MAX</sub> for target volume, bone tissue, and OARs
  - DVH and isodose comparisons (hot spots/cold spots)

## RESULTS

- Gammex 1467 CT-RED curve yields higher HU values within the bony region.
- Differences of up to 595 HU are seen in the bone region of the CT-RED curve.
- Catphan 504 Teflon has density similar to bone, but with lower-Z, resulting in fewer photoelectric interactions at CT energies, resulting in lower CT number.



**Figure 1:** Comparison between CT-RED calibration curves for both phantoms. The green circled area represents the bony tissue portion of the curve, where differences in phantom construction have the greatest effect.

- Results show 2.5% better TPS dose agreement with the delivered dose when utilizing the Gammex 1467 CT-RED curve through bony material.

Energy	Field Sizes (cm <sup>2</sup> )	CATPHAN 504 CT-RED CURVE	GAMMEX 1467 CT-RED CURVE
6MV	5x5	-5.8%	-2.3%
	10x10	-4.4%	-1.6%
	20x20	-2.6%	0.0%
	Average	-4.3%	-1.3%
10MV	5x5	-3.9%	-1.6%
	10x10	-3.3%	-1.5%
	20x20	-2.4%	-0.4%
	Average	-3.2%	-1.2%
10FFFMV	5x5	-4.1%	-1.4%
	10x10	-3.2%	-0.9%
	20x20	-2.4%	-0.4%
	Average	-3.2%	-0.9%
15MV	5x5	-3.3%	-1.0%
	10x10	-5.0%	-1.4%
	20x20	-2.3%	-0.8%
	Average	-3.5%	-1.1%
TOTAL DIFFERENCE BETWEEN PLANNED AND DELIVERED MEASUREMENTS:		-3.6%	-1.1%

**Table 1:** Percentage difference between the TPS calculated dose and the dose measured in the heterogenous phantom containing 2cm bone-equivalent material.

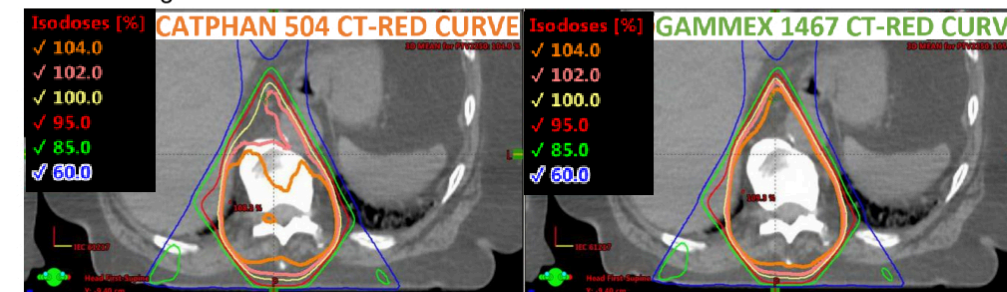
- D<sub>MAX</sub> for target, bone, and OARs was underestimated by up to 2.6% using Catphan 504 CT-RED curve VS Gammex 1467 CT-RED curve.
- Average and maximum target, bone, and OAR D<sub>MEAN</sub> underestimation ranges 0.5 - 1.3% and 1.2 - 2.3%, respectively, using Catphan 504 curve VS Gammex 1467 curve.

DOSE DISCREPANCIES (UNDERESTIMATION) IN HIGH DENSITY PLANS WHEN USING CATPHAN 504 CT-RED CURVE vs USING GAMMEX 1467 CT-RED CURVE				
STRUCTURE	MIN %	MAX %	MEAN %	SD %
Target D <sub>MEAN</sub>	0.4%	2.3%	1.3%	0.6%
Target D <sub>MAX</sub>	0.2%	2.0%	1.2%	0.6%
Bone D <sub>MEAN</sub>	0.1%	1.2%	0.6%	0.5%
Bone D <sub>MAX</sub>	-0.4%	2.3%	1.1%	0.7%
OARs D <sub>MEAN</sub>	0.0%	1.3%	0.5%	0.3%
OARs D <sub>MAX</sub>	0.0%	2.6%	1.1%	0.7%

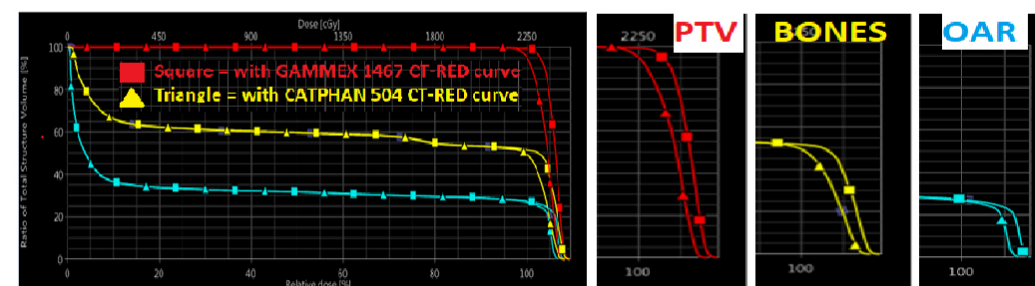
**Table 2:** Structures dose percentage difference between the Gammex clinical patient plans and the Catphan clinical patient plans.

### Clinical Example: Spine Plan

- Dose to the area of high density is underestimated with Catphan 504 CT-RED curve as shown in Figure 2.
- Plan calculated with Catphan 504 CT-RED resulted in lower PTV, Bones, OAR doses compared to same plan recalculated using the Gammex 1467 CT-RED curve as shown in Figure 3.



**Figure 2:** Isodose images of one patient's T-spine plan optimized using the Catphan 504 CT-RED curve and recalculated using the Gammex 1467 CT-RED curve.



**Figure 3:** A patient's spinal plan DVH depicting the differences between the doses to the PTV, Bones (in and surrounding the PTV), and the OAR (spinal cord)

## CONCLUSIONS

- This study investigated how the choice of tissue-mimicking vs. proxy bony materials in a CT density phantom can impact the resulting CT-RED curves and the associated dosimetric effect
- CT density phantoms such as the Gammex 1467 which use tissue-mimicking materials for bony data points result in higher HU values in the bony region compared to phantoms such as the Catphan 504 which use proxy materials
- Dose calculations through bony materials using tissue-mimicking CT-RED curves agree with measured dose approximately 2.5% better compared to proxy curves
- Clinical treatment plans involving bony targets or using beams which traverse significant bony tissue can see underestimated D<sub>MAX</sub> and D<sub>MEAN</sub> for target volumes, bony tissue, and adjacent OARs up to 2.6% and 2.3%, respectively when Teflon is used as a proxy for bony tissue in the CT-RED curve.

## REFERENCES

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