Impact of Image Reconstruction Kernel on CT Number to Proton Stopping Power Calibration

M. CHACKO[1,2], H. GREWAL[1,2], S. RANA[1], D. WU[2], and J. SONNAD[2]
1 The Oklahoma Proton Center, Oklahoma City, OK
2 University of Oklahoma Health Science Center, Oklahoma City, OK

JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

PURPOSE

- Assess the impact of five computer tomography (CT) vendor-specific image reconstruction kernels on Hounsfield Units (HU) to proton relative linear stopping power (pRLSP) calibration curves
- Quantify magnitude of change in water equivalent path length (ΔWEPL) between kernel-specific calibration curve assignment retrospectively on treatment plans

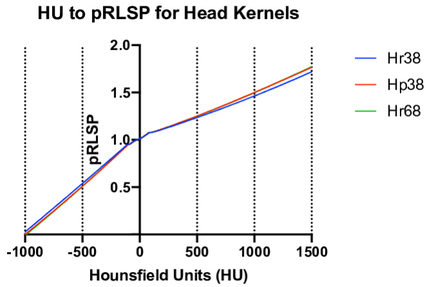
INTRODUCTION

Vendor specific image reconstruction kernels in CT serve to enhance image quality, and are often characterized by features such as sharpness and anatomical region of interest. However, a change in HU can result from variation in image kernel for a given material[1]. Here, we assess the impact of kernel selection on HU to pRLSP calibration.

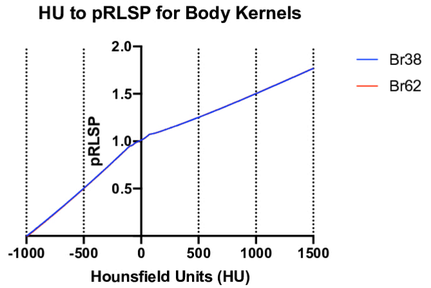
METHOD

- HU to pRLSP calibration curves for associated image reconstruction kernels were generated using an in-house adaptation of the stoichiometric method of Schneider, et al[2].
- Seventeen (17) tissue substitute plugs (Gammex Tissue Characterization Phantom Model 467) were scanned in a Siemens SOMATOM Confidence RT Pro
- Plugs evaluated on individual scans in the center of a 203 mm diameter Lucite phantom filled with deionized water with fixed imaging technique at 120 kVp
- Three head kernels (**Hr38, Hp38, Hr68**) and two body kernels (**Br38, Br68**) were utilized in image reconstruction
- The Hr38 kernel calibration curve was retrospectively applied on patient treatment plans imaged and designed with the Br38 kernel in the CMS XiO planning system
- Five prostate and five lung patient treatment plans were evaluated for changes in the WEPL evaluated at the 95% isodose level (R_{95})

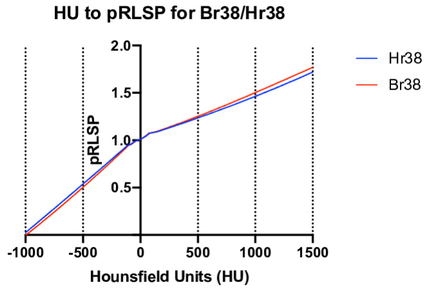
RESULTS



HU to pRLSP calibration curves for head image reconstruction kernels at various sharpness levels

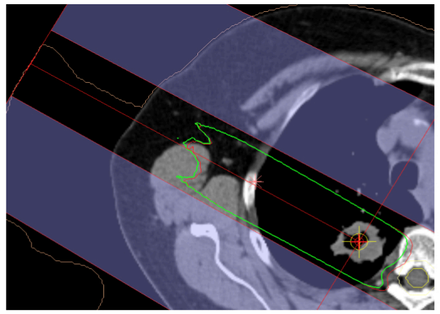


HU to pRLSP calibration curves for body image reconstruction kernels at maximum and minimum available sharpness levels



HU to pRLSP calibration curves for head and body image reconstruction kernels at same sharpness level (38).

HU	Kernel specific pRLSP		Absolute ΔpRLSP
	Hr38	Br38	
-990	0.036	0.007	0.030
-80	0.961	0.956	0.005
0	1.011	1.012	0.000
80	1.074	1.075	0.001
200	1.111	1.117	0.006
450	1.214	1.228	0.014
900	1.415	1.450	0.035
1300	1.613	1.662	0.049
1500	1.719	1.769	0.050



ΔWEPL with incorrect HU to pRLSP curve assignment. The WEPL of Hr38 curve (green) applied on a Br38 CT data set and associated WEPL (red)

Treatment Site	Absolute ΔWEPL (mm)		
	Max	Average	Std Dev
Prostate	1.6	0.2	0.7
Lung	4.1	1.5	1.2

- Between head kernels (Hr38, Hp38, Hr68) the coefficient of variation of pRLSP increased to 2% at 1500 HU
- Largest ΔpRLSP observed between Hr38 and Hr68 in air (-990 HU)
- Analysis from -80 to +1500 HU revealed no difference in pRLSP resulting from either body kernel (Br38 and Br62)
- Differences between head and body kernels of the same sharpness levels were magnified at extreme ends of HU scale
- Impact of ΔWEPL of incorrect calibration curve assignment assessed along beam axes revealed no significant difference for prostate treatment
- Similar analysis revealed significant ($p<0.05$) difference in WEPL for five lung volume treatment plans with maximum and average ΔWEPL of 4.1 mm and 1.4 mm, respectively

CONCLUSIONS

- HU to pRLSP calibration is not interchangeable between Siemens image reconstruction kernels
- Kernel selection has a larger impact on the associated calibration curve between head-specific kernels than between body kernels
- The extreme ends of the HU scale result in largest ΔpRLSP between calibration curves
- A kernel agnostic approach to generating calibration curves shows greatest impact in the lung
- Maximum ΔWEPL in the lung are outside standard range uncertainty margins (2.5-3%) and can be clinically relevant[3]
- Further work includes similar assessment of kernels available on other commercial CT scanners

REFERENCES

1. Völgyes, D., Pedersen, M., Stray-Pedersen, A., Waaler, D., & Martinsen, A. C. T. (2017). How Different Iterative and Filtered Back Projection Kernels Affect Computed Tomography Numbers and Low Contrast Detectability. Journal of Computer Assisted Tomography, 41(1), 75-81
2. Schneider, U., Pedroni, E., & Lomax, A. (1996). The calibration of CT Hounsfield units for radiotherapy treatment planning. Phys Med Biol, 41(1), 111-124
3. Yang, M., Zhu, X. R., Park, P. C., Titt, U., Mohan, R., Virshup, G., . . . Dong, L. (2012). Comprehensive analysis of proton range uncertainties related to patient stopping-power-ratio estimation using the stoichiometric calibration. Physics in Medicine and Biology, 57(13), 4095-4115

CONTACT INFORMATION

Michael Chacko: michael.chacko@okcproton.com