Evaluation of Dual-Energy CT Reconstructed Virtual Monoenergetic Images for Radiation Therapy Treatment Planning

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INTRODUCTION

Dual-energy CT (DECT) utilizes scan data collected at low and high voltages to virtually reconstruct data sets at any energy the user desires. These virtual monoenergetic images (VMIs) have the advantage of increased contrast-to-noise ratio compared to standard scans. In addition, they offer the user the flexibility of generating VMIs of varying energies to assist with visualization of various tissues or contrast agents. While use of DECT is widespread in diagnostic radiology, utilization in radiation therapy is increasing.

This study examines the Dual-Energy Monoenergetic algorithm (DEMA) available for the Siemens SOMATOM Confidence RT Pro simulator, which can create VMIs from 40 keV to 190 keV. Typically, a radiation therapy user would need to collect one scan at a standard 120 kVp for dose calculation in addition to the two DECT scans, or create a separate CT-density curve within the treatment planning system (TPS). This study examines the possibility of utilizing 120 keV VMIs for dose calculation with a standard 120 kVp CT-density curve, eliminating the need for an additional 120 kVp scan, or the complication of multiple curves within the TPS. This could streamline the simulation process, simplify the TPS, and reduce imaging dose for the patient. HU value agreement for multiple materials between a standard 120 kVp scan and 120 keV VMIs was evaluated.

AIM

To evaluate the possibility of utilizing 120 keV VMIs for dose calculation with a standard 120 kVp CT-density curve.

METHOD

The DEMA calculates VMIs by projecting the HU values from the DECT-scans (80 kVp and 140 kVp) to new HU values from known reference curves. A Siemens SOMATOM Confidence RT Pro was used to scan a phantom with calibrated Gammex inserts representing 12 different mass densities, ranging from 0.320 g cm^{-3} to 1.824 g cm^{-3}. First, a scan of the phantom was taken using a tube potential of 120 kVp. Next, two consecutive scans were collected for the DECT with tube potentials of 80 and 140 kVp. VMIs were created from the DECT scans using the DEMA set to 120 keV. Mean HU values were then obtained for each insert from both the standard 120 kVp and 120 keV VMI scans. Mass density vs HU value was plotted for each scan type. The curves were compared and HU differences between the two scan types were tabulated.

RESULTS

Mean HU values for mass densities between 0.320 and 1.095 g cm^{-3} differed by 16.3 ± 34.9 HU or less, indicating good agreement between 120 kVp images and 120 keV VMIs for mass densities equivalent to lung (0.320 g cm^{-3}) through liver (1.095 g cm^{-3}). However, for mass densities representing bone, 1.139 – 1.824 g cm^{-3}, mean HU values differed by a larger amount, from 82.2 ± 38.9 to 405.9 ± 40.9 HU.

Mass Density (g cm^{-3})	Gammex Rod Materials	120 kVp Mean HU Value	120 keV VMI Mean HU Value	Mean HU Difference
0.320	LN-300 Lung	-671.4 ± 21.1	-662.6 ± 27.0	8.8 ± 34.3
0.470	LN-450 Lung	-524.7 ± 32.0	-512.2 ± 35.0	12.5 ± 47.4
0.942	Adipose	-89.4 ± 22.7	-101.8 ± 32.0	12.4 ± 39.2
0.979	Breast	-46.3 ± 19.6	-51.1 ± 29.6	4.8 ± 35.5
1.018	Solid Water	-4.8 ± 20.7	2.4 ± 29.1	7.2 ± 35.7
1.053	Brain	16.5 ± 19.3	0.2 ± 29.1	16.3 ± 34.9
1.095	Liver	71.9 ± 18.4	76.9 ± 29.3	5.0 ± 34.6
1.139	Inner Bone	190.9 ± 19.8	276.1 ± 28.6	85.2 ± 34.8
1.144	B-200 Bone Mineral	191.7 ± 22.1	273.9 ± 32.0	82.2 ± 38.9
1.334	CB2 - 30% $CaCO_3$	416.8 ± 23.8	548.8 ± 33.8	132.0 ± 41.3
1.562	CB2 - 50% $CaCO_3$	769.0 ± 20.8	1040.0 ± 32.2	271.0 ± 38.3
1.824	Cortical Bone	1149.7 ± 26.8	1555.6 ± 30.9	405.9 ± 40.9

Table 1. Mean HU values for various mass densities according to a 120 kVp CT-density curve and reconstructed 120 keV VMIs as well as their mean HU difference.

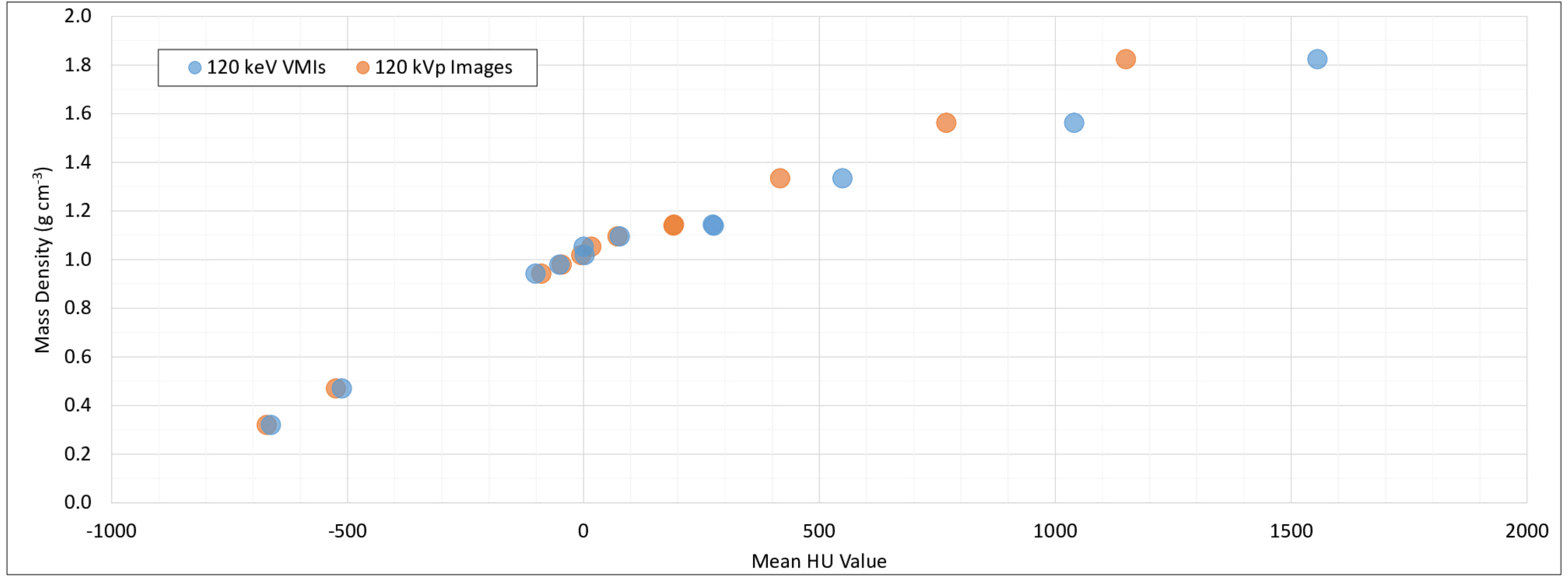

Figure 1. Mass density vs mean HU value for 120 kVp images and 120 keV VMIs.

CONCLUSIONS

Using a standard 120 kVp CT-density curve for dose calculation on 120 keV VMIs would provide many advantages for the patient and radiation therapy user. In addition to increased contrast-to-noise ratio for DECT-scans which allows for improved contouring accuracy, other potential advantages of using one CT-density curve in the TPS are streamlining the simulation process, simplifying the TPS, and reduction of imaging dose for the patient.

The results show that caution should be taken when attempting to use a VMI dataset at 120 keV for radiation therapy treatment planning with a standard 120 kVp CT-density curve due to the potential for inaccurate characterization of bone. While the datasets produce similar HU values for lower density materials, high-density materials, like bone, may show greater differences, potentially leading to errors in dose calculation. Additional research is required to determine the exact nature of any dosimetric differences that may result. However, the majority of errors observed will likely result in ± 2% dose accuracy.[1]

REFERENCES

1. Liu, Q. et al, 2016. The effect of density variation on photon dose calculation and its impact on intensity modulated radiotherapy and stereotactic body radiotherapy. *Medical Physics*, 43(10), pp.5717-5729.

CONTACT INFORMATION

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