Liver lesion volumetry using fully automated lesion segmentation-photon-counting versus dual energy CT

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ABSTRACT

Purpose: To study the accuracy and reproducibility of liver lesion volume measurements using fully automated lesion segmentation at virtual monochromatic imaging (VMI) with photon-counting and dual energy CT (PCCT and DECT).
Methods: A custom-made anthropomorphic liver phantom (size: 25 x 32.5 cm2) was scanned using GE Revolution DECT (GSI, ASIR-V=40%) and Siemens Naeotom PCCT (quantum+, QIR=2), each at 120 kV with three repeats at CTDIvol = 14 mGy. The phantom liver parenchyma was perfused with iodine of 0, 0.68, and 2.38 mg/mL at different slabs to simulate a multi-phase exam. The built-in lesions include iodine and low-density liver, iron oxide, fat, and cyst. 28 visually discernable ellipsoidal or lobular lesions, with nominal contrast from 10 HU to 160 HU and volumes from 0.21 – 8.57 mL, were automatically segmented at 50 – 100 keV using Siemens SyngoVia MM Oncology. The measured volumes were compared to the known values. To account for both accuracy and reproducibility at each keV, F-beta score (F10), with beta equal to 10, was used to place more weight to reproducibility.
Results: F10 scores for the iron oxide, cyst, and fatty lesions ranged from 0.94- 0.99 across 50 -100 keV except at 50 keV where the score of the cyst was 0.84 with DECT. F10 scores for iodinated and low liver density lesions were from 0.70- 0.92 with the maxima of 0.85 and 0.92 at 60 keV, for DECT and PCCT, respectively. In comparison to the ground-truth volumes, the root-mean-square (R.M.S.) errors for all lesions at 60 keV were 12.9% and 6.3%, for DECT and PCCT, respectively.
Conclusion: PCCT with fully automated lesion segmentation resulted in substantially better volume accuracy and reproducibility. 60 keV was found to be optimal for both PCCT and DECT. The R.M.S. error of 6.3% from PCCT suggests reliable lesion volume measurements can be made.

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INTRODUCTION

Liver cancer ranks as the sixth most prevalent cancer globally and the third leading cause of cancer-related mortality. During cancer treatment, there is a need to determine the tumor burden as an indicator of response. A commonly used metric is the modified Response Evaluation Criteria in Solid Tumors (mRECIST), which relies on measuring the longest diameter of viable tumors. However, this diameter-based approach has limitations, particularly in its ability to accurately represent the tumor burden when the tumor burden change is non-isotropic.

Tumor volume is increasingly recognized as a more reliable biomarker for assessing treatment response, as it provides a comprehensive three-dimensional (3D) representation of tumor burden. With advancement of intelligent automatic lesion contour techniques and photon-counting CT (PCCT) technology that enhances CNR and spatial resolution, it becomes possible to achieve accurate hepatic lesion volumetry.

This work aimed to find the optimal virtual monochromatic imaging (VMI) setting for best accuracy and reproducibility of liver lesion volume measurements using fully automated lesion segmentation with photon-counting (PCCT) in comparison with dual energy CT (DECT).

METHODS AND MATERIALS

A custom-made anthropomorphic liver phantom (size: 25 x 32.5 cm2) was scanned using GE Revolution DECT (GSI, ASIR-V=40%) and Siemens Naeotom PCCT (quantum+, QIR=2), each at 120 kV with three repeats at CTDIvol = 14 mGy. The phantom liver parenchyma was perfused with iodine of 0, 0.68, and 2.38 mg/mL at different slabs to simulate a multi-phase exam. The built-in lesions include iodine and low-density liver, iron oxide, fat, and cyst. 28 visually discernable ellipsoidal or lobular lesions, with nominal contrast from 10 HU to 160 HU and volumes from 0.21 – 8.57 mL, were automatically segmented at 50 – 100 keV using Siemens SyngoVia MM Oncology. The measured volumes were compared to the known values. To account for both accuracy and reproducibility at each keV, F-beta score (F10), with beta equal to 10, was used to place more weight to reproducibility.

F10 score: a metric of accuracy and reproducibility combined:

Accuracy: $A = (\overline{V_{meas}} - V_{truth})/V_{truth}$. **(1)**

Reproducibility: $R = (Stdev_{v\_meas})/V_{truth}$. **(2)**

$$F_{10} = (1+10^2)(A \cdot R)/(10^2 A + R). \quad (3)$$

RESULTS

F10 scores for the iron oxide, cyst, and fatty lesions ranged from 0.94- 0.99 across 50 -100 keV except at 50 keV where the score of the cyst was 0.84 with DECT. F10 scores for iodinated and low liver density lesions were from 0.70- 0.92 with the maxima of 0.85 and 0.92 at 60 keV, for DECT and PCCT, respectively. In comparison to the ground-truth volumes, the root-mean-square (R.M.S.) errors for all lesions at 60 keV were 12.9% and 6.3%, for DECT and PCCT, respectively.

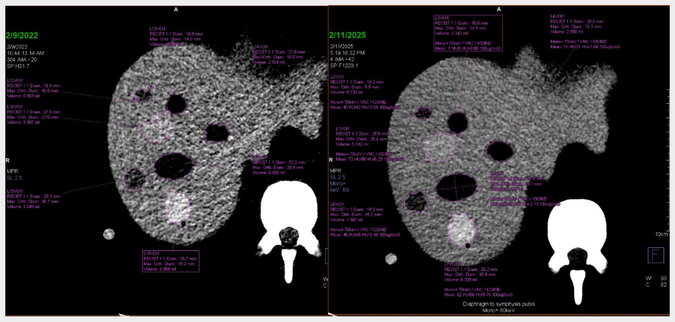

Figure 1: Sample lesion segmentations at 60 keV. Dual energy CT (left) and PCCT (right)

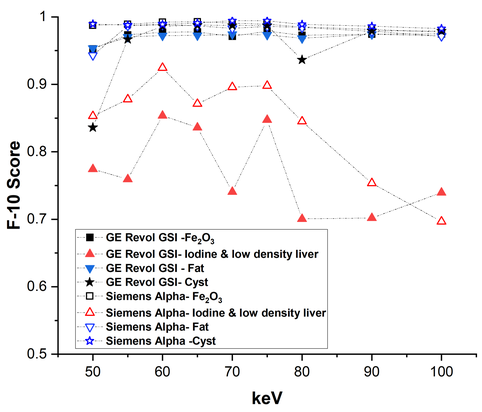

Figure 2: F-10 score for different lesions versus keV

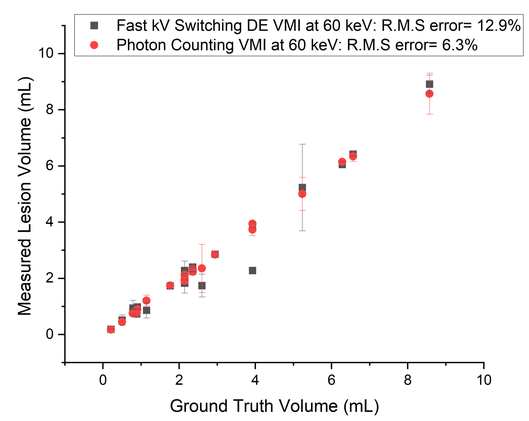

Figure 3: Lesion volume measurement versus the ground truth

DISCUSSION

In this study, we evaluated liver lesion volume assessment using photon-counting CT and dual-energy CT with a custom-designed, industry-fabricated anthropomorphic liver phantom. The phantom simulated the early arterial, late arterial, and venous phases by perfusing the liver parenchyma with iodine at concentrations of 0, 0.68 mg/cm³, and 1.89 mg/cm³, respectively. Embedded within the liver tissue were iodinated lesions of three distinct shapes (spherical, ellipsoidal, and lobulated), with longest dimensions ranging from 12 to 35 mm, volumes between 789 and 8574 mm³, and iodine concentrations from 0.05 to 1.47 mg/cm³ in six lesions with known iodine content. The variations in iodine concentration, lesion shape, and volume were designed to better replicate real-world liver lesions, particularly those that present challenges for quantitative volume analysis, such as non-isotropic shapes, small sizes, or low iodine concentrations.

CONCLUSIONS

PCCT with fully automated lesion segmentation resulted in substantially better volume accuracy and reproducibility. 60 keV was found to be optimal for both PCCT and DECT. The R.M.S. error of 6.3% from PCCT suggests reliable lesion volume measurements can be made.

REFERENCES

1. N. cancer institute NIH, Liver Cancer Causes, Risk Factors, and Prevention, NIH - National Cancer Institute (2022).
2. P. Therasse, S.G. Arbuck, E.A. Eisenhauer, J. Wanders, R.S. Kaplan, L. Rubinstein, J. Verweij, M. Van Glabbeke, A.T. Van Oosterom, M.C. Christian, S.G. Gwyther, New guidelines to evaluate the response to treatment in solid tumors, J. Natl. Cancer Inst. 92 (2000).
3. Ó. Pera, Á. Martínez, C. Möhler, B. Hamans, F. Vega, F. Barral, N. Becerra, R. Jimenez, E. Fernandez-Velilla, J. Quera, M. Algara, Clinical Validation of Siemens' Syngo.via Automatic Contouring System, Adv. Radiat. Oncol. 8 (2023).