Quantitative Image-Guided DECT Interventions: A Potential New Theranostic for Thermochemical Ablation

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INTRODUCTION

- Hepatocellular carcinoma (HCC) affects over 800,000 people worldwide and rising mortality.
- 5-year survival is approximately 18%.
- Often diagnosed late-stage and paired with underlying disease, such as liver cirrhosis (~90% of patients).
- Current treatments include surgical resection, transplantation, local ablation, chemoembolization, radiation therapy, and systemic chemotherapy but efficacy is limited.

THERMOCHEMICAL ABLATION

- Thermochemical ablation (TCA) is an acid/base neutralization reaction of which the products are salt, water, and heat.
  - Induces thermal and osmotic stresses to ablate tissue.
- Novel, minimally invasive therapy for HCC that is delivered directly into the tumor.

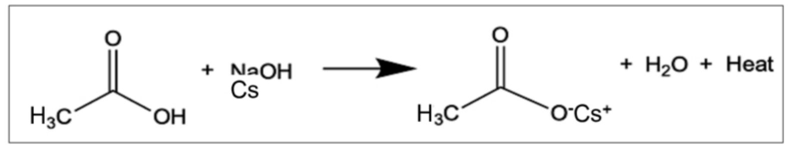

Figure 1: Chemical reaction between acetic acid and cesium hydroxide. The products are cesium acetate, water, and heat, as shown.

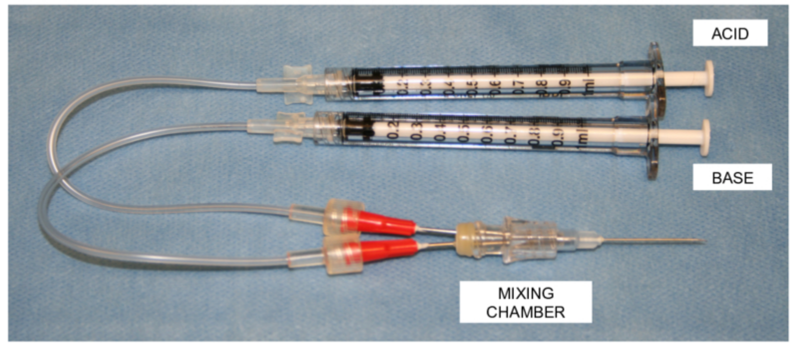

Figure 2: TCA treatment delivery device. Acid and base remain separate until they come together and react in the mixing chamber.

- TCA utilizing reagents with high atomic number (Z) can enable theranostics for real-time CT guidance.
  - The atomic number of Cs (Z=55) enables greater sensitivity compared to that of iodine (Z=53).
  - The Cs product from a TCA reaction can be used for CT guided interventions to ensure complete tumor ablation.
- Quantitative DECT Cs imaging through synchronous or asynchronous calibrations further enables successful mage-guided CT interventions.

PURPOSE

To evaluate the feasibility of cesium hydroxide (CsOH) as a theranostic reagent in TCA when imaged with dual-energy computed tomography (DECT).

METHODS

- Seven serial dilutions of CsOH (Sigma-Aldrich) were made in 15mL centrifuge tubes with concentrations ranging from 0.195 mM-125 mM by serial dilution.
- The seven standards and one vial of water were placed in an elliptical phantom (Multi-Energy CT Phantom, Kyoto Kagaku) and scanned using a split-filter dual-energy system (SOMATOM Edge, Siemens Healthineers).
  - DECT protocol was 90/150Sn kVp, 25mGy $CTDI_{vol}$, 5 consecutive scans
- Images were reconstructed at 1.5 mm slice thickness and 1.0 mm interval, processed with Siemens VNC software, and reformatted to a 5mm image thickness per quantitative imaging protocol.
- Mean CT-number was measured in each vial for each image from ROI's of approximately 7.5 mm in diameter and the standard deviation of the ROI means was calculated.
- The attenuation-enhancement relationship for each CsOH concentration was established and evaluated for linearity using a linear fit model.
- As a feasibility study in *ex vivo* tissue, low concentration detectability of CsOH was evaluated using porcine tissue purchased at a local grocery store using the same imaging protocol.
- Three 0.50 mL injections of 5 different CsOH concentrations (6 mM, 8 mM, 12.5 mM, 25 mM, and 50 mM) were performed approximately 1.5 cm deep.
  - Each dilution was included as a standard in the scan FOV for concentration quantification.
- Attenuation-enhancement relationship was established in the standards and the line profile of each injection was performed.

RESULTS (PHANTOMS)

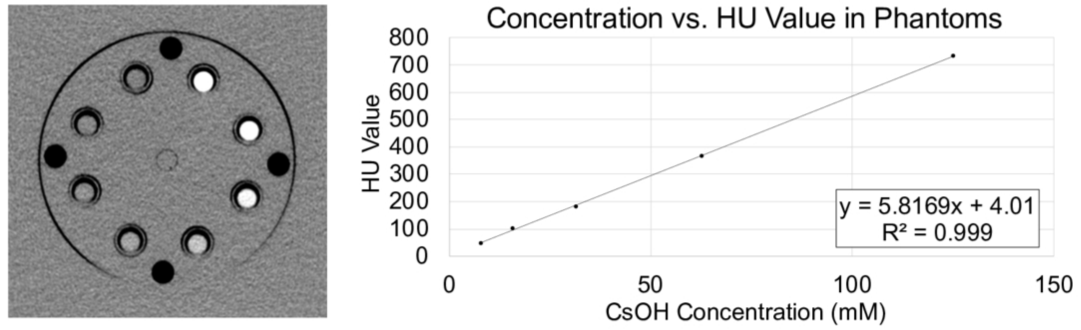

Figure 3: Image of the elliptical phantom used in determination of the CsOH limit of detection (LOD). Standards of CsOH were prepared via serial dilution and spanned a concentration range of 0.195 mM-125 mM. Based on these results, the LOD was determined to be approximately 7.8 mM.

RESULTS (*EX VIVO*)

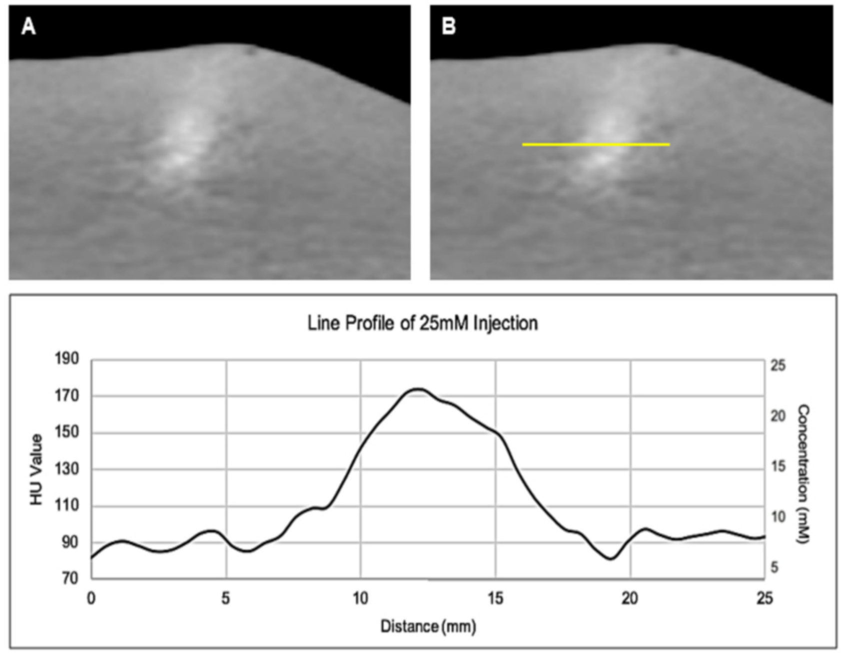

Figure 4: Monoenergetic image (40 keV) (A) and line profile (B) of 0.50 mL, 25 mM injection of CsOH in ex-vivo porcine tissue. Resulting line profile plot of distance (mm) vs. HU is shown.

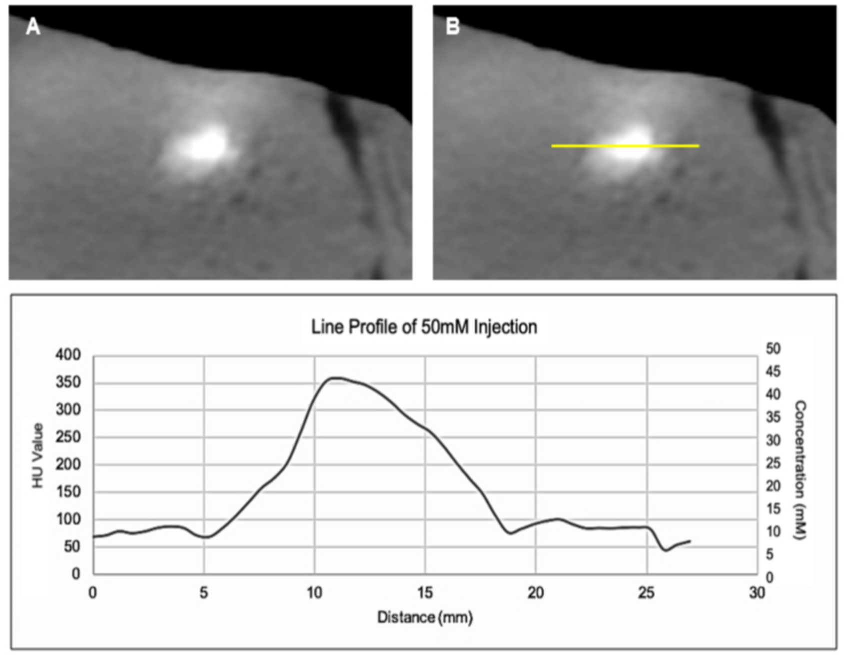

Figure 5: Monoenergetic image (40 keV) (A) and line profile (B) of 0.50 mL, 50 mM injection of CsOH in ex-vivo porcine tissue. Resulting line profile plot of distance (mm) vs. HU is shown.

RESULTS

- In phantoms, the lowest concentration of CsOH detected was 7.8mM.
- Simulated ablation in ex vivo tissues demonstrates qualitative visualization that is correlated to quantitative spatial distribution for image-guided CT interventions.
  - Background CT number in tissue (~80 HU) is greater than phantom.
  - Detection limits determined in phantom are scalar and can be applied to ex vivo tissue or other tissue types for future studies.

CONCLUSIONS

DECT exhibits sufficient sensitivity to spatially track injected CsOH as determined in this proof of concept study. With the use of linear attenuation-enhancement curves, injection profiles can be correlated to concentration of CsOH with the use of synchronous or asynchronous calibration standards. Quantitative assessment of CsOH distribution enables use of DECT as a viable technique to track injectable image-guided ablation and ensure therapeutic delivery.

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