

Iodine Quantification Error Due to Non-Water Backgrounds: A Phantom Study

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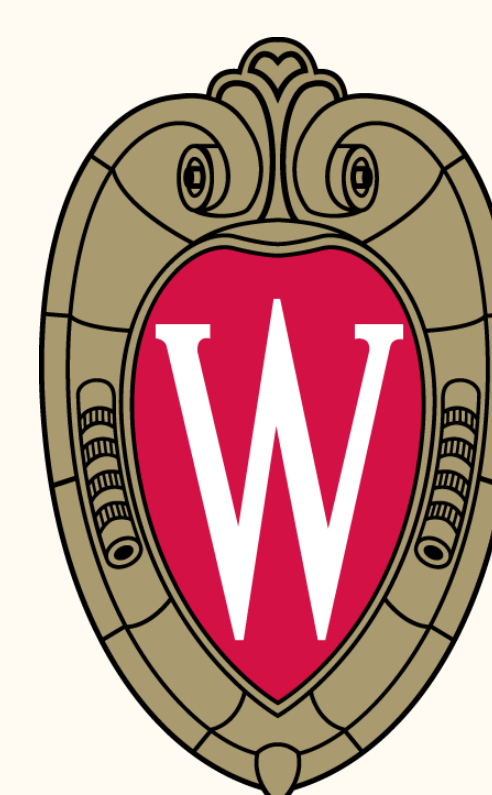
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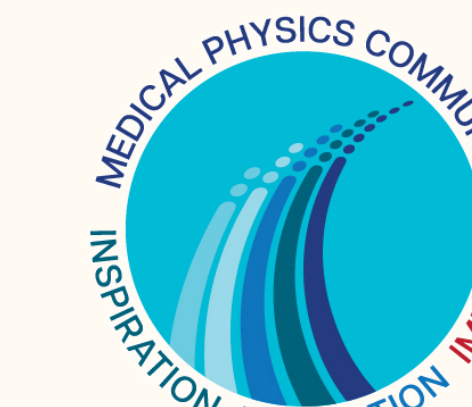
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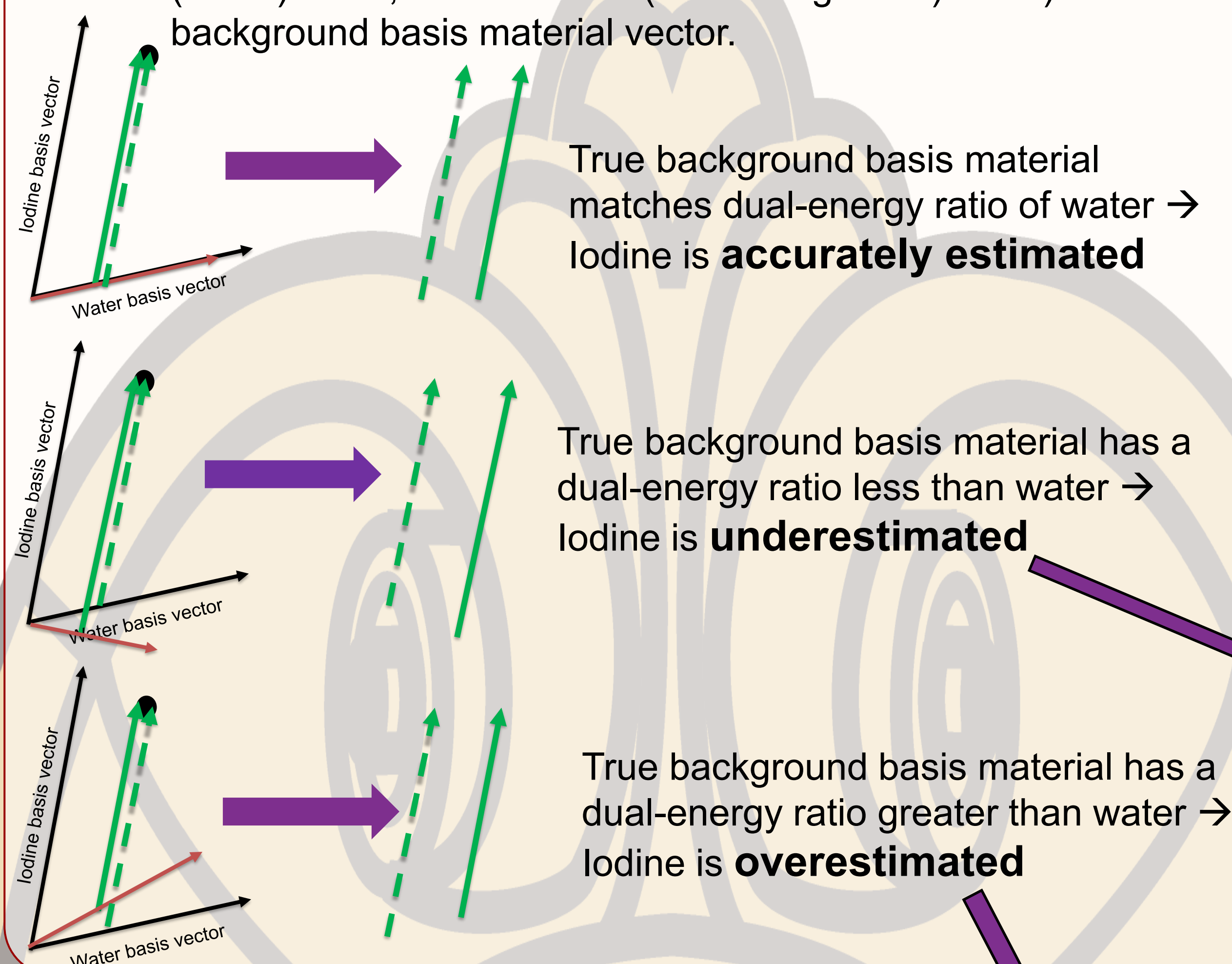


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Background

Previous work on **material quantification** in spectral quantitative CT has noted that the difference between a water background (*ex vivo* conditions) and a non-water background (*in vivo* conditions) when performing material quantification is non-negligible (**Figure 1**). This was previously demonstrated via simulations [1], and the current work demonstrates the expected errors experimentally

Figure 1: Decomposition of a point on an iodine-water basis. Green vector = iodine decomposition values (dashed = iodine (water) basis, solid = iodine (true background) basis). Red = true background basis material vector.



Materials & Methods

Two sets of **custom phantoms** were constructed with the following backgrounds:

- 70% Isopropyl alcohol (30% water)
- 20% NaCl (80% water)

The backgrounds were chosen to encompass the spread of dual-energy ratios observed in tissue relative to water (**Figure 2**)

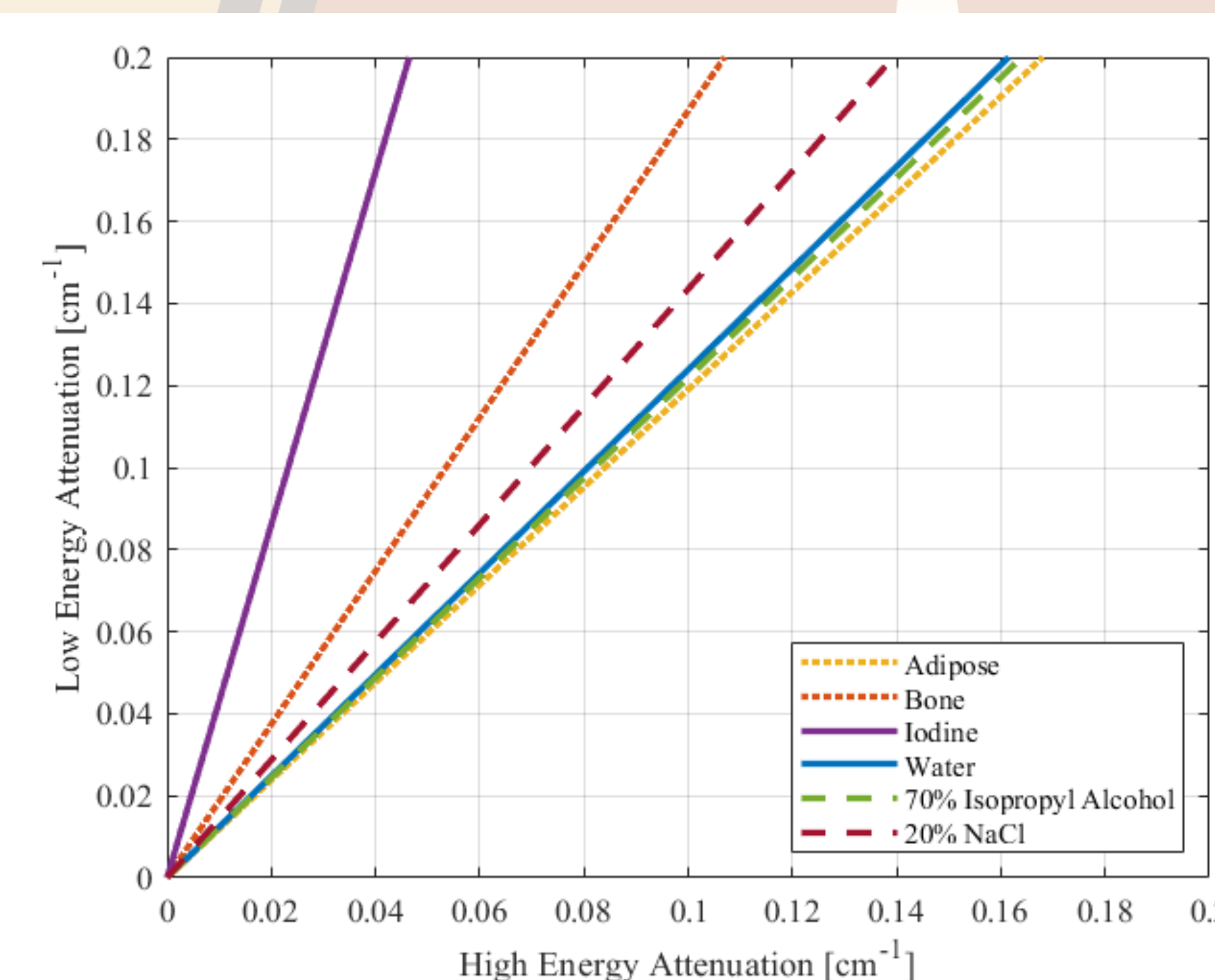
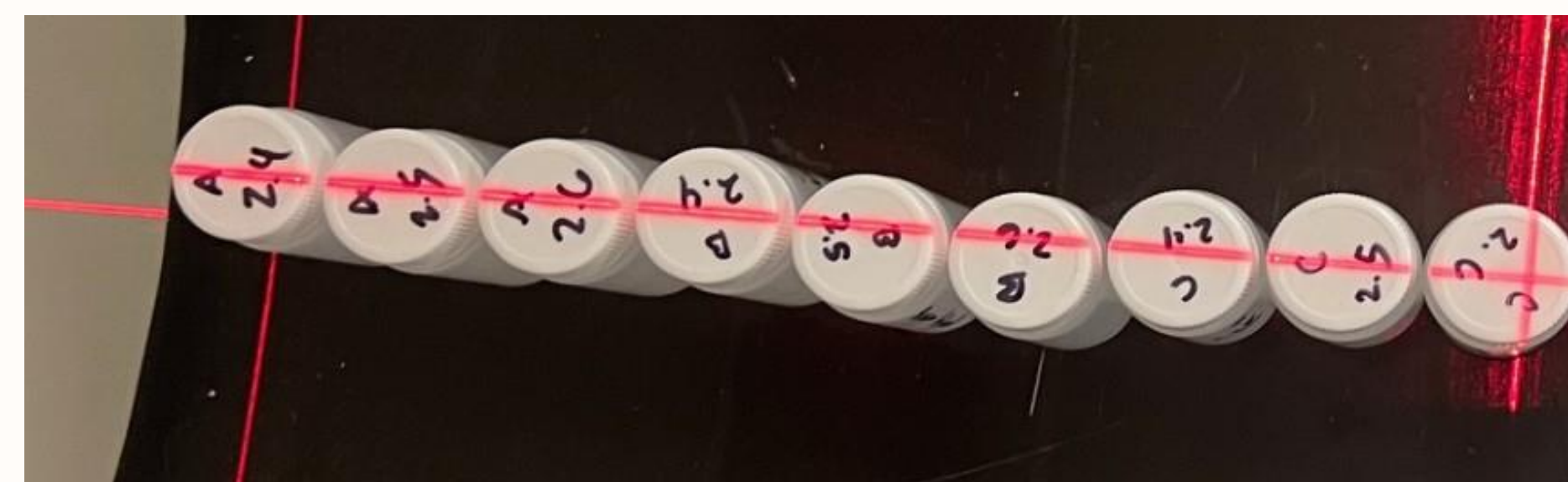


Figure 2: Dual-energy ratios of some common tissues [2] and materials used in this work. 70% isopropyl alcohol has a dual-energy ratio less than water. 20% NaCl has a dual-energy ratio greater than water.

- Sodium iodide (NaI) was added to the vials in concentrations from 0 – 17 mg I/mL to mimic iodinated contrast agent
- Vials were constructed in triplicate and imaged using a kV-switching dual-energy CT system (**Figure 3**)
- **Quantification of iodine** was performed with 4 different material combinations
 - Iodine (water) from the vendor
 - Iodine from the vendor and true background from NIST [3]
 - NaI (stoichiometrically transformed to iodine) from NIST [3] and water from the vendor
 - NaI (stoichiometrically transformed to iodine) and the true background from NIST [3]

Results

Figure 3: All vials were arranged in a line along the center of the table and centered in the CT bore. Note that not all vials are shown in this image.



Figures 4 and 5 legend key:

- Clinical reality today condition: Material decomposition was performed using the vendor's inbuilt iodine and water vectors
- Material decomposition was performed using the vendor's inbuilt iodine vector but the NIST-generated attenuation vector of the true background
- Material decomposition was performed using the NIST-generated attenuation vector of NaI (NaI density converted to iodine density) and the vendor's inbuilt water background vector
- Material decomposition was performed using the NIST-generated attenuation vectors of NaI and the true background

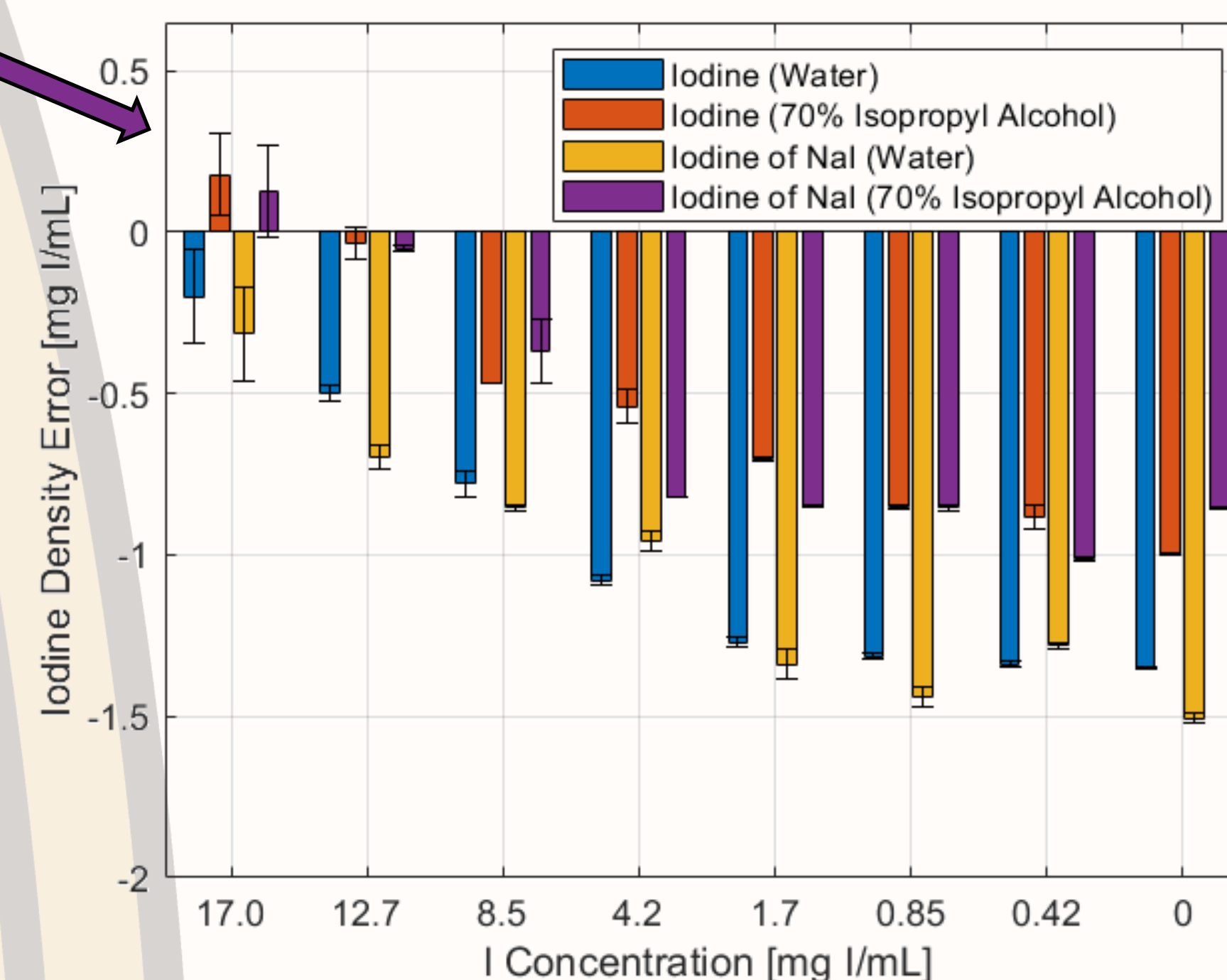
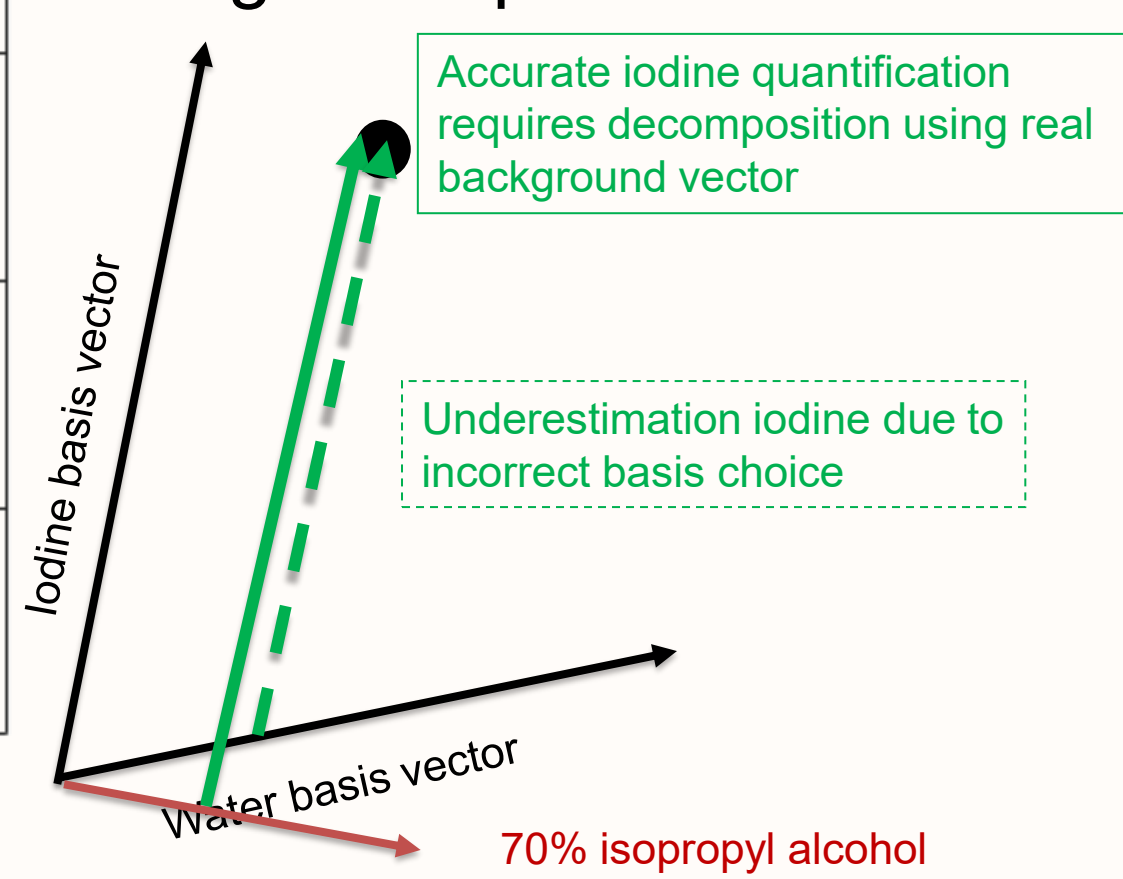


Figure 4: Iodine quantification error (measured iodine density – true iodine density) for the 70% isopropyl alcohol background phantoms.



The 70% isopropyl alcohol background phantoms demonstrate negative errors (iodine density was underestimated), as expected based on **Figure 1**. When decomposed with material pairs that closely match the phantom contents (i.e., iodine (70% isopropyl alcohol) and iodine of NaI (70% isopropyl alcohol)), the errors are reduced. When the iodine (water) decomposition is chosen, maximum iodine error was -1.35 mg I/mL, switching to the iodine of NaI (70% isopropyl alcohol) decomposition reduces this maximum to -1.0 mg I/mL (**25.9%** reduction in iodine error).

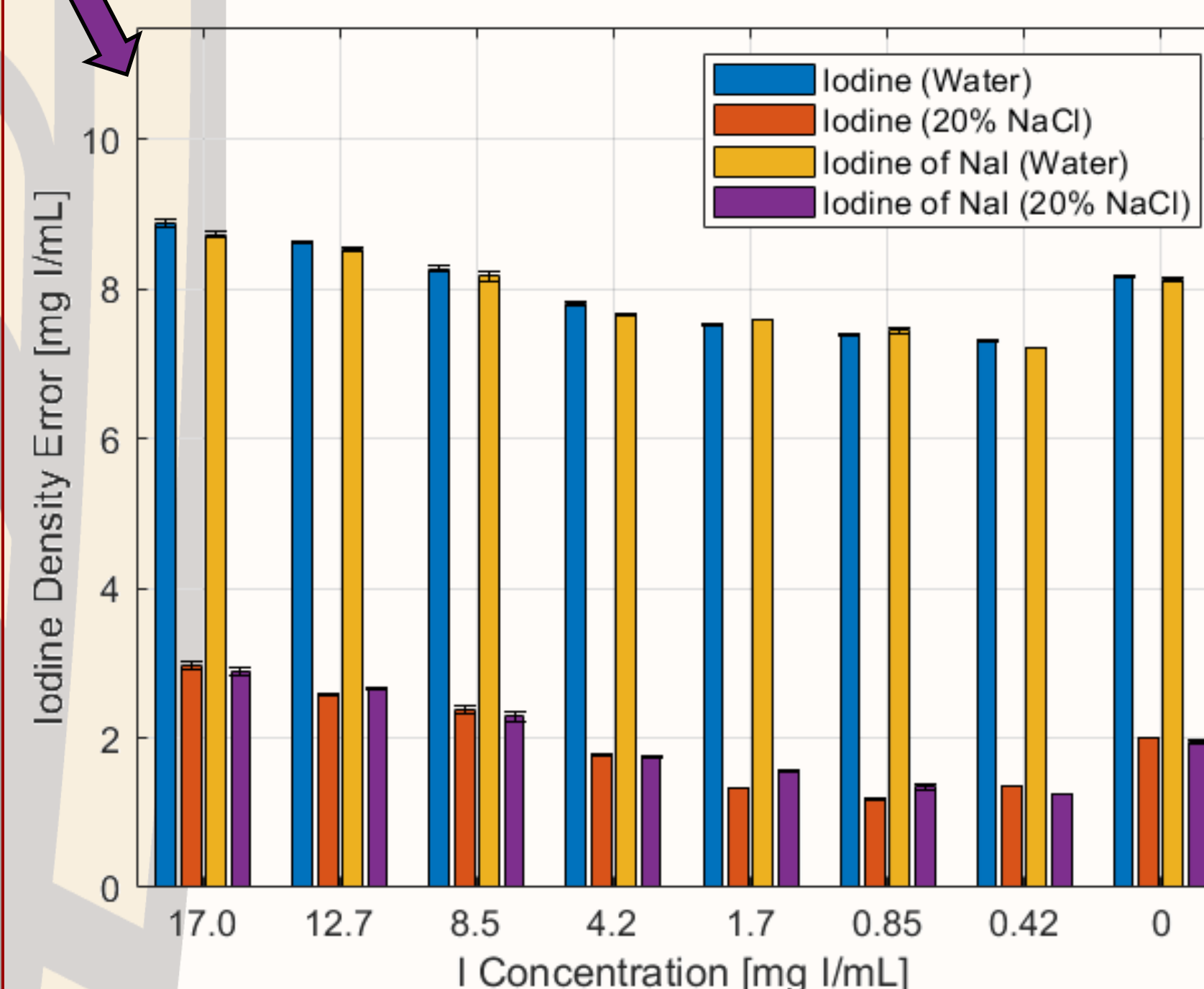
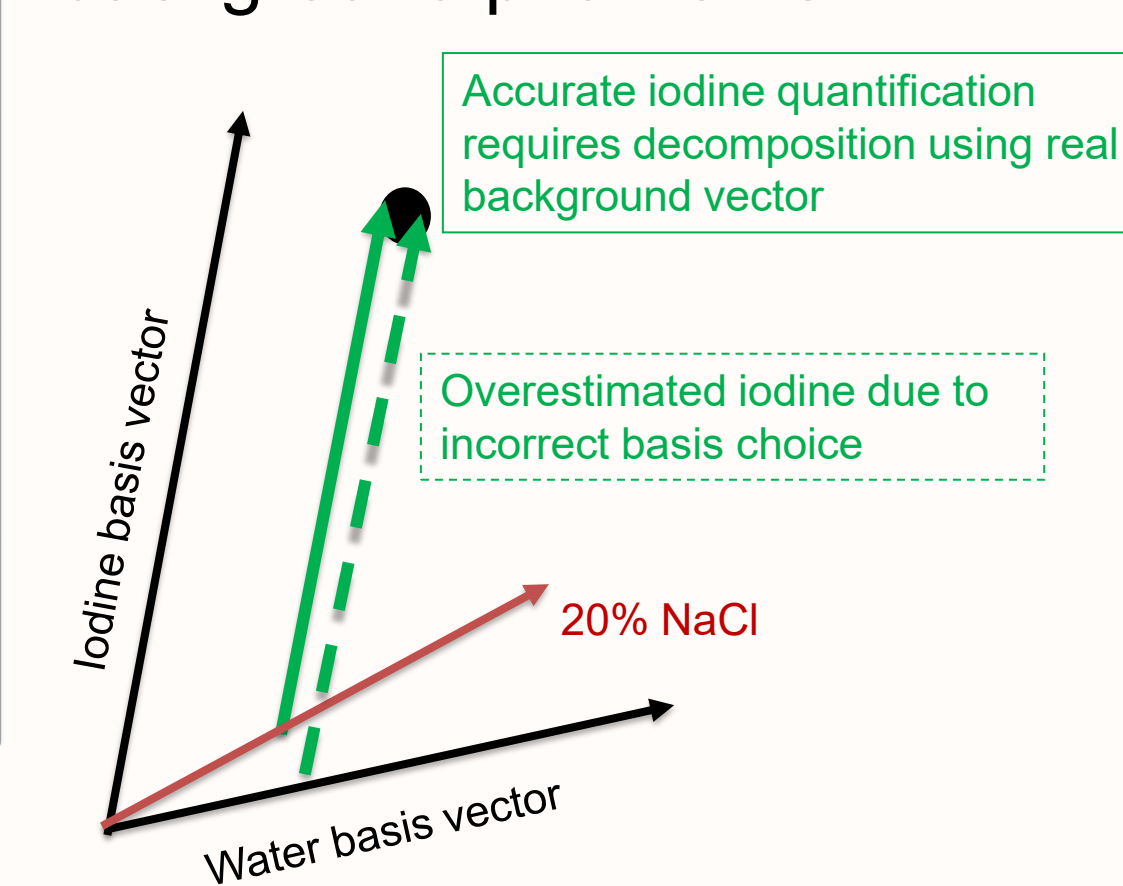


Figure 5: Iodine quantification error (measured iodine density – true iodine density) for the 20% sodium chloride (NaCl) background phantoms.



The 20% NaCl background phantoms demonstrate positive errors (iodine density was overestimated), as expected based on **Figure 1**. When decomposed with material pairs that closely match the phantom contents (i.e., iodine (20% NaCl) and iodine of NaI (20% NaCl)), the errors are reduced. When the iodine (water) decomposition is chosen, the maximum iodine error was 8.88 mg I/mL, switching to the iodine of NaI (20% NaCl) decomposition reduces this maximum to 2.90 mg I/mL (**67.3%** reduction in iodine error).

Key Takeaways

I. Phantom results **confirm** prior simulation studies.

- iodine quantification is **non-negligibly affected** by the choice of material decomposition vectors
- Errors can approach and exceed 100%

II. Iodine quantification is **more accurate** when the material decomposition vectors match phantom contents

- E.g., choosing the iodine of NaI (20% NaCl) decomposition pair over the inbuilt iodine (water) decomposition pair reduced iodine error by up to 67.3%

III. Care must be taken when choosing the material decomposition vectors and when interpreting the results of the decomposition

References

- [1] Salyapongse AM, Szczykutowicz TP. Misinterpretations about CT numbers, material decomposition, and elemental quantification. European Radiology. 2025 Feb;35(2):862-70.
- [2] International Commission on Radiation Units and Measurements (ICRU). Tissue Substitutes in Radiation Dosimetry and Measurement, Report 44 of the International Commission on Radiation Units and Measurements. 1989.
- [3] Berger MJ, Hubbell JH, Seltzer SM, Chang J, Coursey JS, Sukumar R, Zucker DS, Olsen K. XCOM: Photon cross sections database. National Institute of Standards and Technology. 2010. doi: 2010;10:T48G6X.

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