Real-time spectral CT thermometry via physical density for image-guided tumor ablation

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Hepatocellular carcinoma, the fastest rising cause of cancer-related deaths, is commonly treated with percutaneous ablative therapies where tumor cells are destroyed once tissue temperatures reach a lethal threshold. However, high progression and recurrence rates post ablation suggest the need for intraprocedural temperature monitoring to ensure the lethal threshold (>60 °C) is reached and a sufficient safety margin is obtained. Based on our preliminary developments, we can generate physical density maps using spectral CT data. These spectral physical density quantifications enable thermometry by taking advantage of the thermal volumetric expansion equation that relates the change in temperature to physical density changes. To validate the physical density model, an ex vivo bovine muscle was weighed and scanned on a clinical spectral CT scanner with different scanning parameter combinations (collimation, dose, helical/axial scans). Calculated mass from physical density maps and volume demonstrated high accuracy with a maximum percent error of 0.34% (<1.1 grams for a 345 gram sample) and minimal effects of scanning parameters. After validating the accuracy of the physical density maps, the muscle was subjected to heating and cooling while scanning to evaluate the relationship between physical density and temperature. Spectral CT results were continuously generated to calculate physical density maps at different temperatures. A linear relationship between change in temperature and change in physical density was established with strong correlation (R = 0.9781). The reflection of thermal volumetric expansion in physical density quantifications indicate its potential utility for providing real-time temperature feedback to image-guided cancer therapy during ablative procedures for not only hepatocellular carcinoma, but also other types of malignancies.

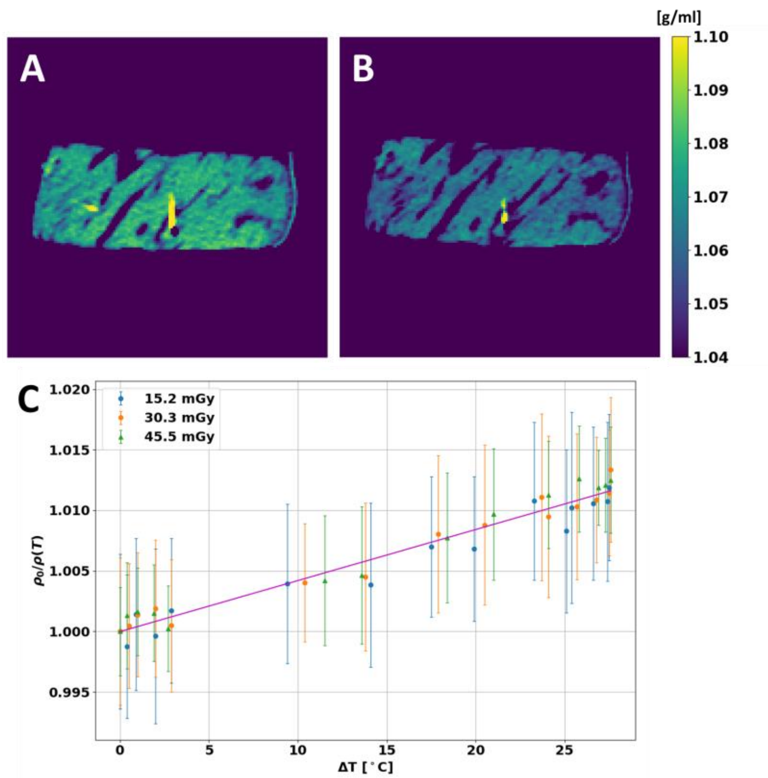

Figure. Changes in physical density during heating and cooling of *ex vivo* bovine muscle. Physical density maps of ex vivo bovine muscle in water (ρ = 1 g/cm^3) at 22 °C (A) and 45.5 °C (B) demonstrated decreased physical density with increased temperatures. (C) The physical density ratio and temperature changes illustrated a linear relationship that reflects thermal volumetric expansion.