Image Quality of Tomographic Thermal Imaging Reconstruction

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INTRODUCTION

An early indicator of radiation induced skin reactions would be a valuable tool for mitigating skin toxicity in radiation therapy patients. Based on previous mouse studies[1], a tomographic reconstruction[2] of skin effusivity using a flash pulsed thermal imaging system could be used for early detection, but translation of the technique to human subjects requires additional development.

METHOD

Defined as the square root of the product of thermal conductivity and volumetric heat capacity, the thermal effusivity is a measure of a materials ability to exchange thermal energy with its environment. Due to the finite speed of heat propagation, one can calculate the effusivity of materials at depth based on the decay of surface temperature after impulse heating. A pulsed thermal imaging system has been employed using two flash lamps and an infrared camera (Figure 1). Vinyl tape with measured thermal properties was used as a fiducial and effusivity values of a custom 3D printed imaging phantom (Figure 2) to assess image quality were performed. The phantom was water filled to provide contrast for the imaging test.

RESULTS

- The thermal effusivity of vinyl tape was first calibrated using the known value of water (1588 W $s^{1/2}/(m^2\ °K)$).
- Calculated values of tape effusivity were found to be 590±7.5 W $s^{1/2}/(m^2\ °K)$
- Effusivity profiles were taken of a 3D printed phantom with a measured effusivity of 450±20 W $s^{1/2}/(m^2\ °K)$.
- After a 3D effusivity reconstruction of the water filled phantom, bar patterns were analyzed and a modulation transfer function (MTF) calculated using a Gaussian fit (Figure 3).
- For water wells in direct contact with the vinyl tape, the best limiting spatial resolution of 7.5 lines / cm producing 10% modulation is achieved at a depth of 0.67mm (Figure 3).
- Water features 0.5 mm below the phantom surface could be resolved at 3.1 lines / cm producing 10% modulation at a depth of 0.75 mm.

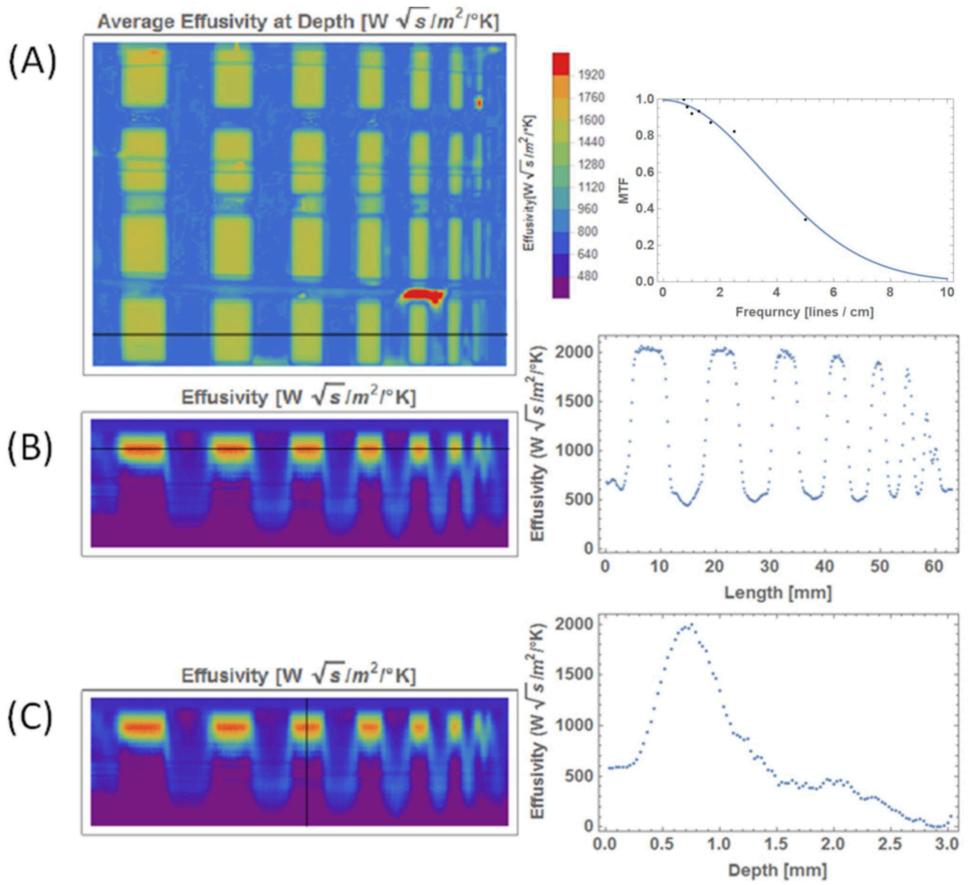

Figure 3. Tomographic thermal effusivity of imaging phantom calculated from surface temperature decay after impulse heating. Average effusivity for all depths is shown in (A) with a black line indicating the transverse slice in (B) and (C). The black lines in (B) and (C) indicate the adjacent plot lineout locations. The calculated MTF from the transverse lineout is shown above the plot in B.

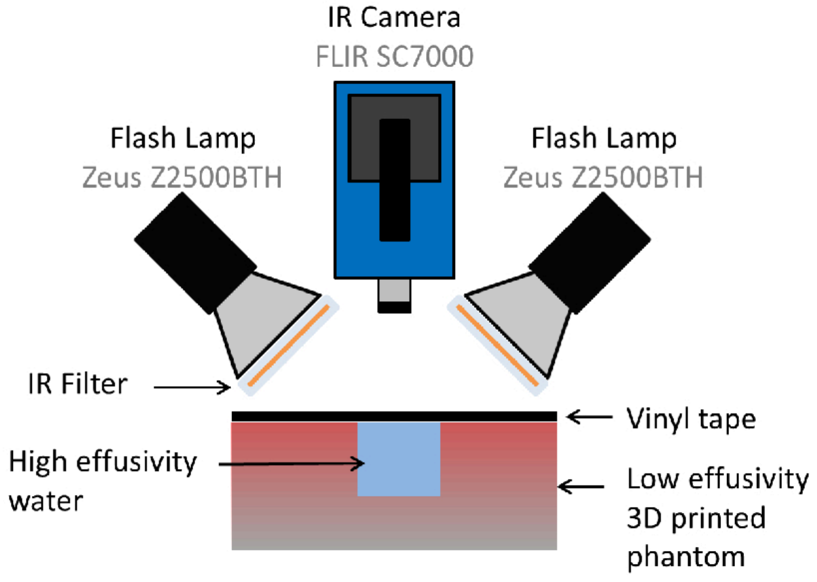

Figure 1. Experimental Setup

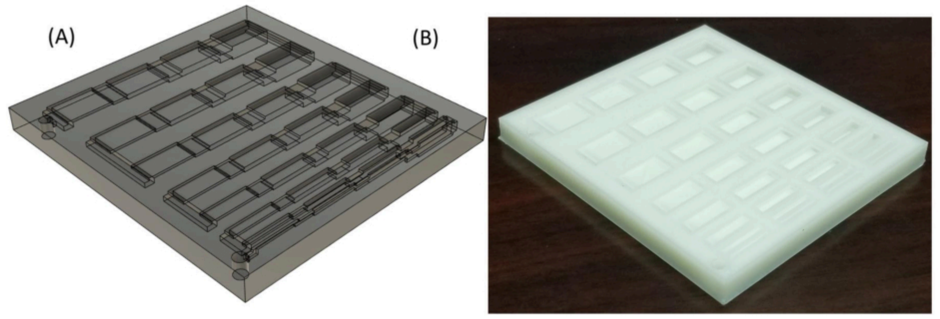

Figure 2. CAD drawing of imaging phantom (A) and 3D printed imaging phantom (B).

CONCLUSIONS

We have validated the precision and repeatability of the measurement apparatus in a previous study[3] and the imaging quality in this study, allowing detection of effusivity changes which may manifest as a precursor to skin toxicities grade 2 or higher.

REFERENCES

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