Quantifying Progression of Skin Inflammation with Hyperspectral Short Wave Infrared Imaging

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Skin disease affects 1 in 4 Americans and costs $75 billion annually. Though visual assessment is a Dermatologist's primary tool, visual assessment is subjective and can lead to misdiagnosis and prolonged patient suffering. Disease can appear more subtly in pigmented skin, and therefore patients with skin of color are more likely to be underdiagnosed and undertreated. Noninvasive skin imaging utilizes the visible and near-infrared, where chromophores like melanin and hemoglobin dominate while water and lipid are effectively invisible. Cutaneous inflammation is characterized by shifts in tissue fluid and lipid content, and therefore a modality operating in the short-wave infrared (SWIR 900-1700 nm), where water and lipid absorption is high and melanin absorption is low, may be useful for direct assessment of inflammation across diverse skin types.

We built a SWIR hyperspectral imaging (SWIR-HSI) system, where 510 reflectance spectra from 881-1710 nm are acquired at each pixel. The ability of SWIR-HSI to assess disease severity was tested in allergic contact dermatitis (ACD), a common inflammatory skin disorder.
Visible photography and SWIR-HSI was obtained daily from one subject with poison ivy-induced ACD over 19 days. ACD lesional skin and intradermal normal saline had matching SWIR-HSI spectral signatures. SWIR-HSI derived pseudo-RGB images (1070nm=R, 1340nm=G, 1605nm=B) provided high-contrast visualization of cutaneous inflammation. Normalizing lesional SWIR-HIS reflectance intensity to unaffected skin defined a tissue fluid index that decreased linearly (r^2 =0.99) as the rash resolved.

Given that only 3 of the 510 channels were utilized, we sought to determine if a broadband SWIR system fitted with 3 bandpass filters would yield a similar result. For each of the 3 wavelengths (1070nm, 1340nm, and 1605nm), we generated an bandpass filtered SWIR image by integrating the reflectance spectra at each pixel around each central wavelength. For a 10nm wide bandpass filter for example, this yielded integrated pixel intensities between 1065-1075nm, 1335-1345 nm, and 1600-1610nm respectively. We applied this algorithm to model the signal from a 10nm and 15 nm bandpass filter around each central wavelength, and then calculated the tissue fluid index from these bandpass filtered images. The tissue fluid index calculated from the 10nm and 15 nm bandpass filters demonstrated the same strong linear decrease with rash resolution as was demonstrated with hyperspectral data analysis. Taken together our work suggests that SWIR-HSI can be used to quantify skin disease activity and can help bolster the design of less complex multi-spectral SWIR imaging systems.