Non-Invasive Erythema Detection Using Spectral Imaging

Sharon Eve Sonenblum, ScM; Stephen Sprigle, PhD, PT; Leanne L. West, MS; Jack W. Wood, MS; Sandeep Prabhakara, MS

**Aim**
This project aims to develop a handheld, clinically-affordable device to identify incipient pressure ulcers. The device will enhance clinicians’ visual assessment of skin.

**Background**
Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Healthy People 2010, believed pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue. Pressure ulcers (PUs) are defined as any lesion caused by unrelied pressure resulting in damage to the underlying tissue.

**Subjects**
70 volunteers were recruited from students, staff and faculty at Georgia Tech. Persons with dark skin were targeted.

- 5% Hispanic
- 8% Asian
- 30% Caucasian
- 57% African American

**Protocol**
- Induce Erythema: Applied pressure for 5 minutes with a spherical indenter to subjects’ calves.
- Capture Images: Image sets were taken with a CCD camera through 12 evenly spaced filters ranging from 400–950nm.
- Multiple image sets were taken with varying gain and shutter settings.

**Analysis**
- Chose the best image for each filter and cropped the 12 best images.
- Performed mathematical combinations of images based on our knowledge of the chromatic features of skin and blood.
- Filtered the combined images and used histogram equalization to further highlight erythema.

**Discussion**
One algorithm that was successful in some dark-skinned subjects (2*550nm-650nm)*950nm took advantage of the known hemoglobin reflectance peaks (oxy-Hb: 542nm and 574nm; deoxy-Hb at 545nm) and built upon current spectroscopic techniques for detecting erythema. Overall, this study shows that spectral imaging might be feasible for the non-invasive detection of erythema and prevention of Stage I Pressure Ulcers. On-going work is using genetic algorithm techniques to identify better filter combinations and algorithms to quantitatively identify erythema. Additionally, these same methods are being applied to identifying bruises.

**Results**
Various filter combinations helped highlight erythema. One algorithm in particular was effective on many dark skinned subjects: (2*550nm-650nm)*950nm.

Below are three examples of filtered and processed erythema. The erythema in Subjects A (light skinned) and B (dark skinned) is more visible when processed by the chosen algorithm. The algorithm, however, does not highlight the erythema sufficiently in Subject C, who is also dark skinned.