Quantifying Photodamage by Noninvasive Mesoscopic Skin Imaging

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Abstract

Ultraviolet light exposure is the major cause for photodamage. Pathologic effects of UV radiation include precancerous actinic keratosis which can progress into squamous cell carcinoma. UV exposures commonly encountered include sunlight and indoor tanning bed exposure. Actinic neoplasia (precancerous actinic keratosis and non-melanoma skin cancer) are highly prevalent in elderly patients with fair skin, and those with lower immune systems. The impact on our healthcare system is substantial, as currently the average annual cost to treat non-melanoma skin cancer is 5 billion dollars [1]. Though often a source of considerable morbidity due to extensive surgical procedures to remove the skin cancers in the normal populations, squamous cell carcinomas are a common source of mortality in immunosuppressed populations, including solid organ transplant recipients.

For prevention and accurate intervention planning, it is crucial to predict if patients have actinic neoplasia. In this study, we investigated the change in optical properties and vascular parameters to characterize skin tissue based on photodamage. Through an IRB-approved clinical trial at the Wright State Physician's Pharmacology Translational Unit, 55 test subjects over the age of 35 years with fair skin and various levels of skin damage were included. Their level of ultraviolet skin damage on their bilateral forearms was photographed and categorized by both practicing dermatologists and by non-invasive mesoscopic imaging technique Spatial Frequency Domain Imaging (SFDI). The SFDI generated maps of absorption, scattering, hemoglobin concentrations, and tissue oxygen saturation. Previously, our group has reported pilot studies that SFDI can be used to identify actinic damage [2].

The Dermatologists scored the same forearm image according to Global Assessment Severity Scale ranging from 0 (less severe) to 9 (the most progressed stage of skin damage) using a validated tool [3]. SFDI was used to assess levels of scattering and hemoglobin concentration in the subjects' skin. The dermatologists' scores showed agreement over the extreme stages of skin damage, but in the moderate groupings more variance existed. Further methods to find the best statistical method will be explored, along with different criteria to correlate the SFDI results. Ideally, a non-invasive imaging (such as SFDI) will be used in clinical settings for frequent monitoring of patients at high risk for actinic neoplasia.

Hypothesis

We hypothesized that there is a correlation between the data gathered by the non-invasive mesocopic imaging and the clinical dermatologists' skin damage assessment.

Methods

SFDI Mapping

- The wide field, non contact machine gathers data on the basis of multiple parameters: reflectance mode, vascular mode, and fluorescence imaging mode.
- Maps of absorption and scattering, hemoglobin concentrations, and tissue oxygen saturation were graphed for each subject's arm (see Table I).
- The WSU Engineering Department analyzed results using a custom MATLAB software to fit data at each pixel.

Tissue Vascular Parameters Obtained from absorption parameter (μ_a)	What Parameter Measures	Hypothesized Significance related to At-Risk Skin
Hb-Deoxy-hemoglobin concentration (microMolar)	Oxygen consumption, local metabolism	INCREASED In At-Risk Skin. Increased numbers of metabolically active cells, especially actinically damaged keratinocytes and fibroblasts which are senescent but are more metabolically active. Moreover, more chronic immune cells in dermis.
HbO2-Oxy-hemoglobin concentration (microMolar)	Oxygen delivery, supply	INCREASED In At-Risk Skin. Increased blood flow.
THC-total hemoglobin concentration (microMolar) (Hb+HbO2)	More vasculature more blood content	INCREASED In At-Risk Skin Increased vasculature with overall increased blood flow.
StO2-tissue oxygen saturation (%)	HbO2/THC, shows how much is the oxygenation part.	NO CHANGE In At-Risk Skin Tissue oxygenation is not increased due to increased metabolism and delivery. Efficient exchange from surrounding.
Tissue Structure Parameter Obtained from scattering parameter (μ_s')	**What Parameter Measures**	**Hypothesized Significance related to At-Risk Skin**
Scattering parameter related to Mie scattering in skin.	Related to cell concentration, cell size	INCREASED In At-Risk Skin Increased numbers of cells.

Table 1. Comparison of Imaging and Biochemical/Physiological Parameters.

Dermatologist Scoring Criteria

- 10 Dermatologists rated each photograph according to the Global Assessment Severity Scale via McKenzie et al publication scoring guidelines [3].
- The physicians rated each forearm from 0-9, including duplicate images to maintain and measure levels of consistency.
- The scoring ranged from 0 (less severe) to 9 (the most progressed stage of skin damage).

Results

Figure 1. Mesoscopic Imaging Apparatus (SFDI)
a) Schematic diagram.
b) SFDI instrument for imaging lesions on patient arm.

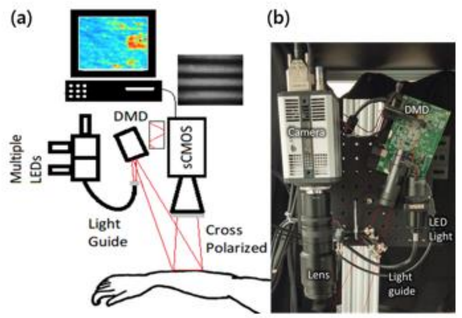


Figure 2. Clinical Assessment of Photodamage
a) Dermatologists' clinical scores of skin damage.
b) Examples of mild, moderate, severe photodamage analyzed by Clinical Dermatologists.

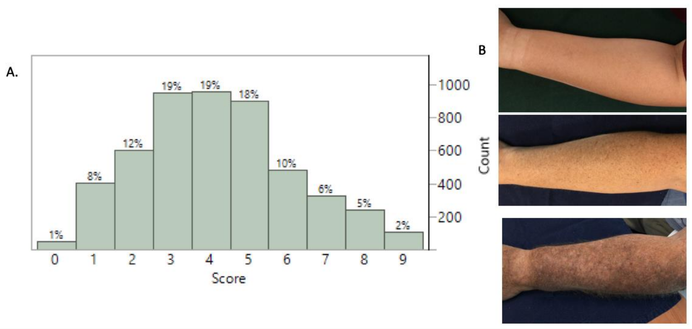


Figure 3. Examples of Imaging Data in mild, moderate and severe photodamaged skin

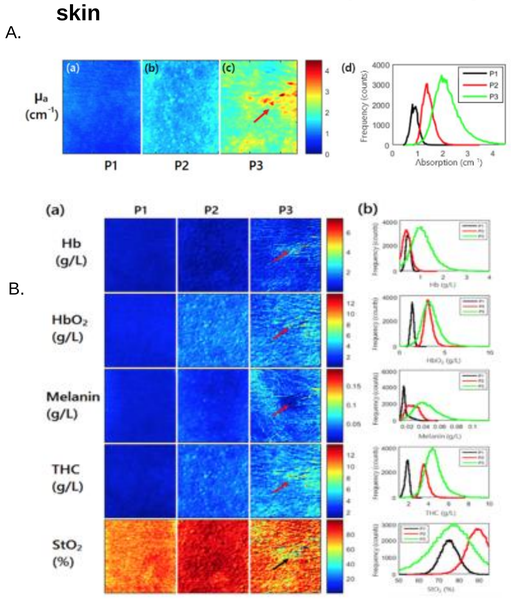
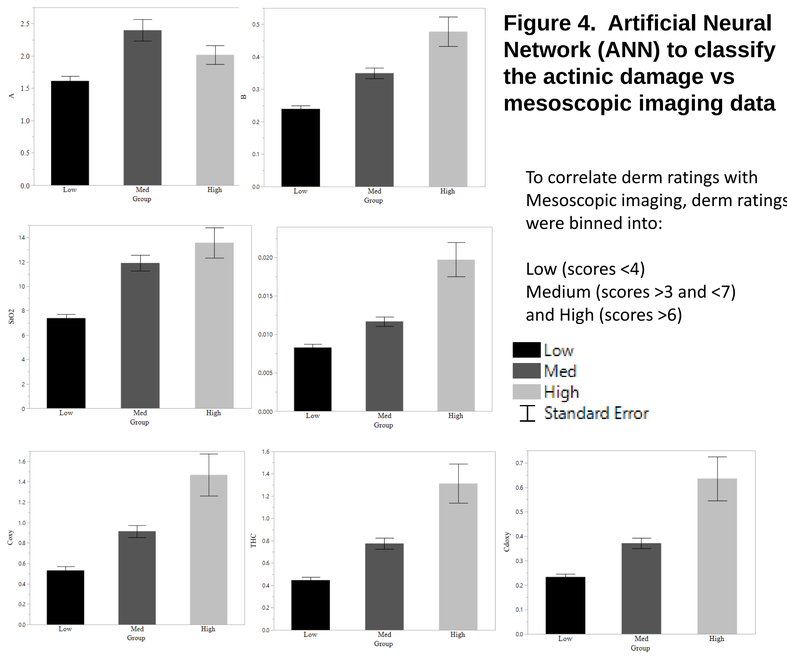


Figure 3A. (a), (b), (c) Absorption imaging maps for three subjects at 590nm. Red arrows highlight the visible lesion for subject with severe photodamage (P3). (d) Histograms of the absorption parameter for the subjects with mild (P1), moderate (P2), and severe damage (P3) at 590 nm.

Figure 3B. Physiological parameter quantified from absorption maps. (a) shows the spatial maps for each parameter for subjects with mild (P1), moderate (P2), and severe (P3) photodamage. Arrows highlight the visible lesion for subject P3. (b) shows the summary histogram of each parameter.

Results

Figure 4. Artificial Neural Network (ANN) to classify the actinic damage vs mesoscopic imaging data



To correlate derm ratings with Mesoscopic imaging, derm ratings were binned into:

Low (scores <4)
Medium (scores >3 and <7) and High (scores >6)

Low
Med
High
Standard Error

Summary and Conclusions

Dermatologic Analysis

- The Dermatologists' scores had variance both within their internal controls and also between each other's assessments. Scores tended towards the middle values (Fig. 2). Thus, their ratings were grouped into low (scores <4), medium (scores >3 and <7), and high (scores >6) levels of photodamage.

SFDI Mapping

- SFDI can provide quantitative maps along the parameters of optical and vascular modes to classify precancerous lesions in humans.
- Photodamage can be correlated to levels of scattering and hemoglobin concentration, and data from A, B, Coxy, Cdoxy, and Sto2 was used.
- To classify the photodamage mesoscopic imaging data an Artificial Neural Network (ANN) was found to provide accuracy that was better than chance.
- Through further quantified monitoring, additional information on the progress of pre-cancer to malignant staging can be given to patients.

- **We believe this non-invasive technology could be used to not only assess skin for risk for actinic neoplasia, but also as a tool to be able to study field carcinogenesis [4].**

References

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Acknowledgments

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