Assessment of human burn scars with optical coherence tomography by imaging the attenuation coefficient of tissue after vascular masking

Peijun Gong
Robert A. McLaughlin
Yih Miin Liew
Peter R. T. Munro
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Abstract. The formation of burn-scar tissue in human skin profoundly alters, among other things, the structure of the dermis. We present a method to characterize dermal scar tissue by the measurement of the near-infrared attenuation coefficient using optical coherence tomography (OCT). To generate accurate en face parametric images of attenuation, we found it critical to first identify (using speckle decorrelation) and mask the tissue vasculature from the three-dimensional OCT data. The resulting attenuation coefficients in the vasculature-masked regions of the dermis of human burn-scar patients are lower in hypertrophic (3.8 ± 0.4 mm⁻¹) and normotrophic (4.2 ± 0.9 mm⁻¹) scars than in contralateral or adjacent normal skin (6.3 ± 0.5 mm⁻¹). Our results suggest that the attenuation coefficient of vasculature-masked tissue could be used as an objective means to assess human burn scars. © 2014 Society of Photo-Optical Instrumentation Engineers (SPIE) [DOI: 10.1117/1.JBO.19.2.021111]

Keywords: optical coherence tomography; parametric imaging; burn scars; hypertrophic scars; attenuation coefficient; scar assessment; collagen; vasculature.

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1 Introduction

Wound healing after burn injury involves the sequential phases of inflammation, tissue formation, and tissue remodeling. Scar formation during this process is a natural facet of healing, and hypertrophic scars are one pathology arising from an excessive response to injury during healing. Such scars are characterized by prolific neovascularization; and excessive content and abnormal arrangement of collagen. In normal skin, collagen is arranged in a "basket-weave"-like structure, whereas collagen in hypertrophic scars is more unidirectionally aligned. Previous studies have shown that, compared with normal skin, hypertrophic scars contain collagen fibrils with reduced diameter and have higher water content. Various techniques are available or under investigation for the treatment of pathological scars including surgery, pressure therapy, corticosteroid injections, silicone gel sheeting, radiotherapy, and laser therapy. Evaluating the efficacy of these clinical treatments typically requires the longitudinal assessment of a scar's severity. Current scar assessment methods are primarily based on the direct observation and palpation of the features of scars. For example, the Vancouver Scar Scale uses observer assessment of pigmentation, vascularity, pliability, and height to characterize the scar. Assessment with such methods is inevitably somewhat subjective, leading to high inter-observer variability. There is reported research on alternative, less subjective techniques. Electron microscopy has been used to study the characteristic morphological profiles of pathological scars but requires histological slices of excised scar tissue. Multiphoton and confocal microscopies and have been applied to scar tissue or wounds, ex vivo and in vivo, including for high-resolution imaging of collagen and elastic fiber components. Ultrasound imaging has been investigated as a means of assessing the thickness of burn scars in pediatric patients noninvasively. Other techniques, such as laser Doppler perfusion imaging and laser speckle perfusion imaging, have used the degree of vascularization as a surrogate indicator of scar status.

Changes in tissue morphology in pathological scarring can result in changes in the optical properties of the tissue in the near-infrared wavelength range. This has driven a growing body of work exploring the use of optical coherence tomography (OCT) in scar assessment. OCT is a noninvasive imaging modality capable of acquiring three-dimensional (3-D) scans of tissue at resolutions from 1 to 20 μm from superficial tissues at depths of up to 1 to 2 mm. The morphological features of normal and diseased skin have been studied in vivo with OCT imaging. Wound healing has been evaluated noninvasively by high-resolution OCT, and polarization-sensitive (PS) OCT has been used to measure the birefringence of both normal and...