In vivo assessment of human burn scars through automated quantification of vascularity using optical coherence tomography

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Abstract. In scars arising from burns, objective assessment of vascularity is important in the early identification of pathological scarring, and in the assessment of progression and treatment response. We demonstrate the first clinical assessment and automated quantification of vascularity in cutaneous burn scars of human patients in vivo that uses optical coherence tomography (OCT). Scar microvasculature was delineated in three-dimensional OCT images using speckle decorrelation. The diameter and area density of blood vessels were automatically quantified. A substantial increase was observed in the measured density of vasculature in hypertrophic scar tissues (38%) when compared against normal, unscarred skin (22%). A proliferation of larger vessels (diameter ≥ 100 μm) was revealed in hypertrophic scarring, which was absent from normal scars and normal skin over the investigated physical depth range of 600 μm. This study establishes the feasibility of this methodology as a means of clinical monitoring of scar progression. © 2012 Society of Photo-Optical Instrumentation Engineers (SPIE). [DOI: 10.1117/1.JBO.18.6.061213]

Keywords: in vivo imaging; optical coherence tomography; scar assessment; skin; speckle decorrelation; vascularity; vasculature.

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1 Introduction

Burn injury is an important global health issue, with nearly 11 million incidences world-wide of fire-related burn injuries reported annually.1 Burn damage to the skin may also arise from a range of other causes, including contact with hot liquids or surfaces, electricity, radiation, chemicals, and moving surfaces (friction).2

A broad spectrum of scars may result in response to a burn injury. A normotrophic scar is the best clinical endpoint as the scarred normal skin. Normal scar exhibits similar characteristics (thickness, color, pigmentation, and pliability) to those of the surrounding, unscarred normal skin.3 For some individuals, pathological scar conditions, such as hypertrophic scarring, can develop. A hypertrophic scar is characterized by a high degree of angiogenesis and an over-proliferation of collagen synthesis that is restricted to the original wound margin. It presents clinically as a red, raised, and rigid lesion, which may produce scar contractures (i.e., tightening of tissue) when located over joints.4–6 Hypertrophic scarring is associated with delayed healing of burns and occurs in more than 60% of patients.3,6,7 It is a common outcome of a deep dermal burn and occurs within weeks of the injury. This type of scarring often increases in size for three to six months8 and subsequent regression and maturation may take more than two years.

Examination of scar progression is important in the early diagnosis and treatment of pathological scarring, and in the assessment of response to treatment. A potent clinical indicator is the redness of the scar, which is indicative of the degree of angiogenesis.10,11 Angiogenesis occurs initially during the proliferation phase of the wound healing process and may continue long after wound closure. A red scar has a higher risk of becoming hypertrophic than a pale scar.10 Regression of vascularity is expected toward scar maturity with notable reduction of redness, becoming comparable to the surrounding normal skin.12,13 Visual assessment of color is a standard clinical approach to rate scar vascularity, and is used in protocols such as the Vancouver Scar Scale.14,15 However, the unaided visual assessment of scar redness can be highly subjective, with limited sensitivity and significant inter-observer variability. Previous attempts to objectively quantify scar vascularity have been performed within histological studies,16–19 although the invasive nature of histological analysis precludes its use in longitudinal assessments.

Several noninvasive techniques to measure scar vascularity have been investigated. These include the use of a reflectance meter to measure the erythema index of scars and photography or videography to record scar color.10 Video capillaroscopy has been used to evaluate the differences in the vasculature of hypertrophic scars and healthy skin.20 It acquires image data with high resolution but is limited to extremely superficial vessels (within ~200 μm).21 Laser Doppler flowmetry (LDF) has been used to noninvasively measure blood flow at a single point in a hypertrophic scar.22,23 Laser Doppler perfusion imaging (LDI)24 and laser speckle perfusion imaging (LSPI)25 extend the point...