Introduction

Optical coherence tomography (OCT) is a non-invasive imaging modality that allows real time high-definition cross-sectional visualization of tissues.

Conventional OCT was introduced in dermatology in 1997 and has shown benefit in evaluating malignancies and inflammatory skin disorders.\textsuperscript{1,2} High-definition optical coherence tomography (HD-OCT) scanners have recently been developed; they provide a higher resolution and horizontal, in addition to vertical, sectional imaging compared to conventional OCT.

Abignano et al. previously demonstrated the use of OCT in quantifying skin fibrosis in systemic sclerosis.\textsuperscript{3} Here, we illustrate how HD-OCT may be used to aid the bedside diagnosis of morphea.

High-definition Optical Coherence Tomography (HD-OCT)

The HD-OCT scanner (Figure 1) non-invasively visualizes skin layers up to 1mm in depth and provides up to 3 µm high-resolution images. Three dimensional views of the epidermal layers, the dermal-epidermal junction and reticular dermis can be generated in one second.

\textbf{Figure 1.} High-Definition Optical Coherence Tomography scanner for dermatology application - HD-OCT (Skintell®; Agfa Healthcare, Belgium)
In vivo High-definition Optical Coherence Tomography: A bedside diagnostic aid for morphea

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HD-OCT Principles

• Use near infrared light
• Incident light is backscattered from the structure being imaged (Figure 2)
• Light propagating through tissue is attenuated by wavelength-dependent scattering and wavelength-dependent absorption
• Contrast mainly originates from the change of the refractive index

Case Report- Part 1

A middle-aged man presented with a one-year history of worsening itchy rashes over his lower limbs and back. Examination revealed indurated brown-colored patches over his lower limbs (Figure 3). Inflamed patches were noted over his hips, abdomen and back. Systemic review was normal; specifically there was no arthralgia, dysphagia or Raynaud phenomenon. Anti-nuclear and extractable nuclear antigen antibodies were negative.

Lesional skin biopsy over his right shin revealed histological features consistent with morphea. HD-OCT imaging was performed at sites of indurated skin (including skin adjacent to the biopsy site), inflamed patches and normal skin.

Figure 2. Typical OCT setup. Adapted from Walsman SM, Bansal R, Smith SD. Posterior segment optical coherence tomography in glaucoma. Journal of Current Glaucoma Practice [http://www.jaypeejournals.com]

Figure 3. Clinical photograph taken over the lower limbs- Brown indurated plaques over the lower limbs with intervening areas of normal-looking skin (pre-treatment).
The patient was treated with bath phototherapy with ultraviolet A (PUVA) twice weekly. By 4 months post-treatment, the inflamed plaques had resolved and the indurated skin had markedly softened. HD-OCT imaging was repeated over the same sites as previously performed.

Comparing the HD-OCT images, the dermis of indurated skin appeared homogenously dark compared to normal skin, associated with less and smaller blood vessels (Figures 4a-e). Between inflamed and normal skin, no clear differences could be visualized. Software analysis of dermal pixel brightness was subsequently performed (ImageJ, National Institutes of Health, USA), using 30 equidistant vertical slices in each image. Pre-treatment, the indurated dermis was darker and more homogenous (mean 56.7±35.0 on an 8-bit grayscale ranging from 0-255) compared to normal skin (mean 105.9±53.2). Four months post-treatment, this difference was still evident, but brightness in the indurated dermis had increased (70.0±25.4).
Discussion

In HD-OCT, the comparative uniform darkness (hypo-refractiveness) in the dermis of indurated skin, evident visually and reflecting a lower score with smaller standard deviation in image analysis, denotes homogeneity of the dermal components. This was correlated with the histological findings of thickening and hyalinization of the collagen in the dermis with associated decrease in adnexal structures, blood vessels and inflammatory infiltrate. In contrast, there was marked heterogeneity in the dermis of both inflamed and normal skin, in which variations in refractile indexes manifested as non-uniform brightness. With treatment, induration of affected skin was clinically markedly reduced, and there was a corresponding increase in dermal brightness upon HD-OCT imaging.

HD-OCT can image skin to a depth of 570um and is therefore appropriate for conditions affecting the deeper dermis, such as morphoea. It has a resolution of 3um in both the slice and en face planes, and is thus capable of detecting the structures and cells affected in morphea, namely the collagen bundles, blood vessels and inflammatory infiltrates.

Conclusions

1. HD-OCT can be a non-invasive bedside tool to aid in the diagnosis and monitoring of morphea.

2. In imaging of morphea using HD-OCT, the dermis of indurated skin appears uniformly dark (hypo-refractive) due to the closely-packed, thickened and hyalinized collagen.

3. With treatment and clinical improvement, the HD-OCT findings of lesional skin approaches that of unaffected skin.

References