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Letter to the Editor

Improved quality of optical coherence tomography imaging of basal cell carcinomas using speckle reduction

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Abstract

Background: Optical coherence tomography (OCT) is a possible imaging method for delineation of non-melanoma skin cancer. Speckle noise is the dominant noise contribution in OCT images; it limits the ability to identify cellular structures especially skin cancer.
Questions addressed: This report suggests a method for improving OCT image quality for skin cancer imaging.
Experimental design: OCT is an optical imaging method analogous to ultrasound. Two basal cell carcinomas (BCC) were imaged using an OCT speckle reduction technique (SR-OCT) based on repeated scanning by altering the distance between the probe and the surface of the skin.
Results: SR-OCT resulted in improved visualisation and more accurate thickness measurements in BCC lesions.
Conclusion: This OCT speckle reduction method led to improved visualisation and better defined delineations in two BCC lesions. Thus, OCT was improved to a clinically relevant level when imaging BCC lesions.

Keywords: basal cell carcinoma – optical coherence tomography – speckle

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Background

More than one million patients a year in the US alone (1) are affected by non-melanoma skin cancer (NMSC). Clinical diagnosis is not 100% accurate (2) and imaging methods may potentially improve diagnostic accuracy. Optical coherence tomography (OCT) is a potential imaging method for diagnosis and delineation of NMSC (3–7) and has been applied for NMSC with promising results in several studies (3–13). Speckle noise is the dominant noise contribution in OCT images and it limits the ability to identify cellular structures essential for diagnosis of a variety of diseases, especially skin cancer. The presence of speckle is a result of interference of light reflected by closely spaced scatterers; it can reduce the contrast and suppresses the visibility of structural details. Different techniques to suppress speckle noise have been used in ophthalmic OCT imaging resulting in a better signal-to-noise ratio and a better delineation of retinal layers (14–16). The most promising speckle reduction methods are based on compounding techniques where repeated OCT scans with varying speckle noise are acquired. In this way, the speckle noise can be suppressed by registration and averaging of the images.

An adjunct non-invasive tool for diagnosing skin cancer would potentially have several advantages: it would have a large diagnostic impact in patients with many suspicious skin tumors or field cancerisation (17) and it may also have a therapeutic impact as the efficacy of non-surgical treatment options for basal cell carcinomas (BCC) seem to be at least partly dependent on tumor depth (1,18–20). Two studies compared OCT measurement of maximum depth in BCC lesions with corresponding depth in histology and found good agreement in the lesions where the depth could be estimated from the OCT images [20 lesions (4) and 34 lesions (7), respectively]. However, a tendency for OCT to overestimate tumor thickness was emphasised.

Questions addressed

This case report describes the image enhancement that can be obtained in dermatological OCT imaging by applying so-called spatial diversity compounding to imaging and measurement of two BCC.

Methods

The OCT system used was developed at the Technical University of Denmark and is a mobile, fibre-based, time-domain and real-time OCT system (21). The OCT probe is applied directly to the skin, using ultrasound gel as an optical coupling medium to improve image quality (22). The light source is a superluminescent diode with a centre wavelength of 1340 nm. The axial resolution is 9 μm (in tissue), and the lateral resolution is 24 μm. The maximum penetration depth in skin is 2.0 mm. In order to reduce the speckle noise, we apply a so-called spatial diversity compounding scheme, where the focal plane of the beam is being shifted relative to the sample, without moving the sample (23). These focal shifts are obtained by altering the distance between the probe and the surface of the sample by using a motorised actuator (Thorlabs Z612B, Thorlabs, Newton, New Jersey). The spatial diversity compounding is based on the fact that the number of scatterers contributing to the speckle pattern changes when the focal plane moves. A numerical aperture of size 0.05 was found sufficient to de-correlate the speckle patterns when shifting the focal plane in steps of 50 μm. Typically, 7–10 images with de-correlated speckle noise are recorded and combined into one average image (23). To determine whether speckle-reduced OCT (SR-OCT) improves image quality; we compared OCT with SR-OCT in two BCC lesions. In the literature, a break-up of the characteristic layering of normal skin (24–26) is demonstrated in OCT images of NMSC (3–7) and the BCC basaloid island cell clusters are described as dark rounded areas, sometimes surrounded by a white area that represents the surrounding stroma.

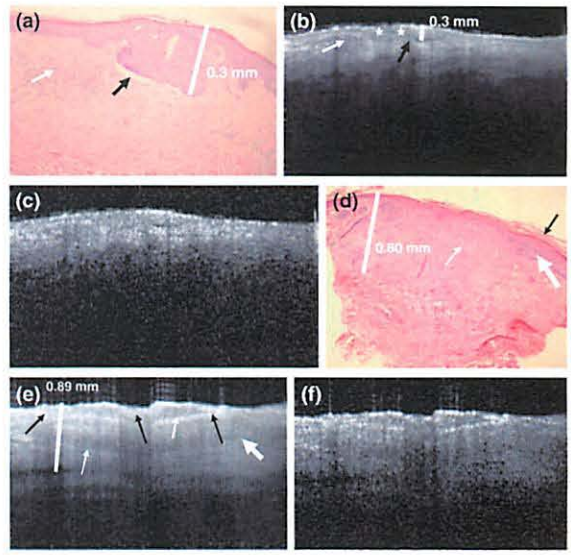

Figure 1. Comparison of HE-stained histology sections of two BCC lesions with SR-OCT and OCT images of the lesions. (a) A histology section from a superficial BCC lesion, which was clinically diagnosed as an actinic keratosis; a pink, scaly, not so well-defined lesion on the lower arm. (b) The corresponding SR-OCT image. Feature characteristic of a BCC was identified: darker round areas (asterisk) and separation of basaloid carcinoma cells and stroma (black arrow) and an inflammatory infiltrate (white arrow). Thickness is indicated by a white bar in (a) and (b). (c) The regular OCT image corresponding image. (d) A histology section of a larger BCC lesion and (e) is the corresponding SR-OCT image. The white bars again indicate the BCC thickness. The fat white arrow indicates an inflammatory infiltrate, the black arrows indicate hyperkeratosis. Thin white arrows indicate stromal reaction. In (e) shadows are seen below black arrows due to the decreased penetration of light in hyperkeratosis. (f) A regular OCT image of the same lesion.

Results

Figure 1 shows images from two patients with BCC lesions. Compared with the regular OCT scans, the SR-OCT images have more well-defined boundaries, and the grainy structure caused by speckle is suppressed. In Fig. 1b, characteristic dark lobules of a BCC lesion are seen in the OCT image (6,7,10). This particular lesion clinically appeared as an actinic keratosis on the lower arm, but was identified as a BCC in histology, Fig. 1a. The regular OCT image, Fig. 1c, did not provide the morphological details of dark lobules.

Also in the second lesion, Fig. 1d, it is observed that the SR-OCT image, Fig. 1e contains more morphological structures than the regular image, Fig. 1f. More specifically, we can observe well-defined basaloid tumor cell islands, hyper-reflective hyperkeratosis, stromal tissue surrounding the BCC islands, and an inflammatory infiltrate. In both SR-OCT images, the base of the BCC lesion was better defined than in regular OCT images, thus making thickness estimations more feasible. Histology assessment of the tumor depths was 0.30 and 0.80 mm, which corresponded well to the measurements of 0.30 and 0.89 mm estimated from the SR-OCT images. Thus SR-OCT results in improved visualisation and thickness measurements in the BCC lesions. Hence, the SR-OCT images carried more diagnostic information than the regular OCT images.

Conclusion

Currently, both high-frequency ultrasound and OCT imaging have been demonstrated potentially useful for thickness estimation and delineation of NMSC lesions (2,7). Both techniques have a tendency to overestimate tumor thickness. One possibility to overcome this obstacle would be to enhance OCT image quality; either through speckle reduction or by improving resolution with ultra broadband light sources. Other possibilities for improving or enhancing information from OCT images are polarisation sensitive OCT (2), which provides functional information and Fourier domain OCT, which has a higher signal-to-noise ratio

(27). Alternative methods for differentiating NMSC from normal skin include chemical (28), THz-radiation (29) as well as electrical (30) techniques and some of these methods may in the future be combined with imaging methods to extract even more information.

The compounding scheme for speckle reduction described here has produced better quality OCT imaging, which may be clinically meaningful. Further regular studies of specificity and sensitivity are, however, needed to establish the exact degree of diagnostic improvement in NMSC provided by SR-OCT imaging.

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