Hemangioma vascular lesion characterization by Optical Coherence Tomography attenuation coefficient

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Abstract: OCT was used to obtain optical attenuation coefficient from normal and vascular skin lesion, with a simple decay model. Lesioned skin presented 9.2% higher values than normal, which could be helpful for early hemangioma diagnosis.
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1. Introduction

Hemangioma vascular lesions are common childhood tumors appearing mainly in the neck and head. It affects 10% of children worldwide [1]. In most cases the lesions does not bring consequences for the patient's health, although some patient can develop complications caused by tissue deformities. In extreme cases, it could be a life risk.

The most common treatment methods are corticosteroids application, pulsed dye laser therapy and surgical excision [1].

The early diagnosis of the lesion could lead to an early treatment and a reduction on its aesthetic and psychological consequences. The gold standard for diagnosis at cellular level is the excisional biopsy, but it is an invasive technique and it could cause side effects [2]. So noninvasive techniques for diagnosis are preferable over the excisional biopsy. The alternatives available for this propose are the computed tomography (CT) scan, magnetic resonance imaging (MRI) and ultrasound (US) echography [1, 3].

For the clinical application both CT and MRI present the drawback related to its price. On the other hand, US echography is present at hospitals besides being more affordable and already used for some vascular lesions diagnostics [1, 4, 5]. Despite its large presence in hospitals, the US are limited to evaluate hemangioma vascular lesions. The US technique is able to obtain deep images in tissue but its resolution is of a few millimeters, which is not enough to image the first layer of skin tissue and its capillaries.

In the early 1990s Optical coherence tomography (OCT) was introduced and covers this US limitation. OCT can perform cross-sectional images of biological tissues, similar to US images, but using broadband light sources reaching micrometer resolution. Now a day OCT is a widely used technique for ophthalmology [6] , but finds applications in dermatology [7, 8].

As well as US, it is possible to explore the Doppler Effect on OCT to acquire image of moving particles and thus imaging functional blood flow, known as Doppler OCT. [9].

One way to characterize the hemangioma vascular lesions by using OCT is by measuring the presence of blood vessels in the upper dermis. In a previous work, coupling the morphological analyses of OCT with the functional blood-flow capability of Doppler OCT the size and position of blood vessels were measure [10]. It was possible to differentiate hemangioma vascular lesions from skin Port-Wine Stain lesions.

Despite of the clear match between Doppler OCT measurements capability and the hemangioma vascular lesions features, acquisition of a Doppler OCT image in which the blood vessels clearly appear is not an easy task. Additionally, the hemangioma vascular lesions have a large variability of morphological features interfering into the Doppler OCT solution. Therefore, the development of additional methods to Doppler OCT could enhance the capability to differentiate hemangioma vascular lesions using OCT.

Due to setup features, it is possible to use the OCT to measure the attenuation coefficient of the biological tissue under investigation. This optical parameter has been explored to characterize glaucoma effects on retinal nerve fibers [6]. The use of this optical parameter could be helpful for the hemangioma vascular lesion diagnosis.

The aim of this work was to evaluate the use of the attenuation coefficient acquired from the OCT signal to differentiate between hemangioma vascular lesions from normal skin.

2. Material and Methods

The study was approved by the Ethical Committee of the IMIP (protocol no. 728.993) and the images were collected after the patient, or his legal representative, signed the informed consent.

To acquire the OCT image it was used a swept source OCT system (OCS1300SS; Thorlabs GmBH, Dachau/Munich, Germany) at 1325 nm of central wavelength and 100 nm of bandwidth with an output power of 10 mW. The axial and transverse resolution are 9 μm and 18 μm respectively. The final image size of the system was set to 512 x 1024 pixel (axial x lateral) and the frame rate was 25 frames / s.

The OCT images used in this work was obtained from a patient with hemangioma vascular lesion in his hand (Fig. 1). In order to allow comparison, the images were acquired in two regions, normal and lesion. It was acquired 50 images acquisition on normal region and 541 images acquisition on lesion region.

Fig. 1. Patient with hemangioma vascular lesion on his hand.

Assuming that the attenuation coefficient is constant throughout the optical path length α, the OCT signal decay is described by the Beer-Lambert law (equation 1). To any column of the OCT image, signal can be described by this model.

$$I = Ce^{-2\alpha x} \quad (1)$$

were C is a proportionality constant that we will ignore, without any loss for this, and x is the depth position.

To estimate the attenuation coefficient of the tissue an exponential can fit to the signal. However, it requires a nonlinear fit and it is not a well-behaved solution. Thereby we take the natural logarithm of the equation to allow a linear fit (equation 2), so the slope of the linear fit is equal to two times the attenuation coefficient.

$$\ln(I) = \ln(C) - 2\alpha x \quad (2)$$

3. Results

The Fig. 2 present a typical OCT image for the hemangioma vascular lesion (a) and normal skin (b), respectively, obtained in this study. As can be noted from Fig. 2 there is no clear difference on OCT images between the two regions. It was not possible to observe in this data set the presence of vessels highlighting the importance of having complementary methods to the Doppler OCT.

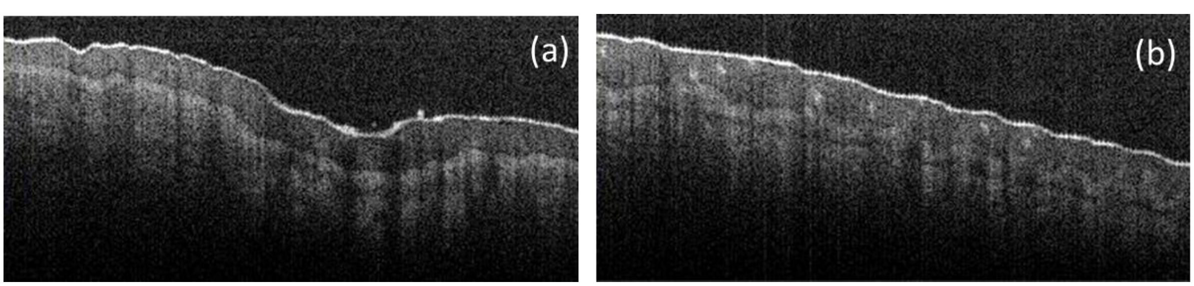

Fig. 2. OCT image of hemangioma vascular lesion (a) and normal skin (b).

To each of the 1024 column in each OCT image, it was applied the linear fit to a linearized signal, described on section 2, and the attenuation coefficient was obtained, totalizing 553984 data points of attenuation coefficient for lesion region and 51200 data points for normal region.

The Fig.3 shows a normalized histogram of the attenuation coefficient obtained for the lesion and normal region.

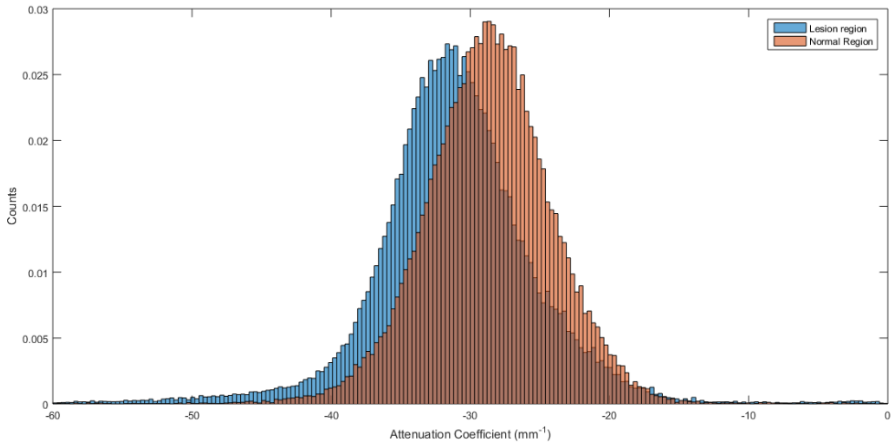

Fig. 3. Histogram of the attenuation coefficient for hemangioma vascular lesion and normal skin region.

It is possible to see on Fig. 3 that the two distributions have different mean values, 31.199(9) mm^{-1} for lesion region and 28.706(21) mm^{-1} for the normal region. The similarity between the two groups was statistically tested by a t-test. The groups were considered different ($p < 0.005$).

4. Conclusion

In this work, we evaluated the use of the attenuation coefficient acquired from the OCT signal to differentiate between hemangioma vascular lesions from normal skin. Early diagnosis in children is important to guide treatment and prevent the lesion progress. For this propose, we applied the simplest signal decay model to OCT signal. We assumed a constant attenuation coefficient for the signal throughout the entire region observed by the OCT. Despite the limitations of this simple model, it was possible to observe a statistical difference ($p < 0.005$) between the values obtained from the region of the hemangioma vascular lesion and the normal skin. The use of this approach could be complementary to other signal analyses based on OCT. Furthermore, for future works, other more complex models for the signal decay could be developed to improve the method specificity.

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