Real-time diagnosis of vascular lesions with OCT

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Abstract: Non-invasive real-time imaging of vascular lesions is performed with OCT, with 10-20 micrometers resolutions at 1mm depth. The images reveal different skin layers and blood vessels (Doppler effect), the growth of which indicates vascular tumor.

OCIS codes: (110.4500) Optical coherence tomography; (170.0110) Imaging systems; (170.1610) Clinical applications ; (170.4580) Optical diagnostics for medicine.

1. Introduction

Among vascular lesions, infantile hemangiomas are the most common vascular tumors of childhood, affecting around 5 % of all births (figure 1). Although most lesions proliferate from abnormal vessel grow and then involute with minimal consequence, a significant minority may develop complications, including infection or ulceration, and can thus be disfiguring, functionally significant, or, rarely, life-threatening [1-2].

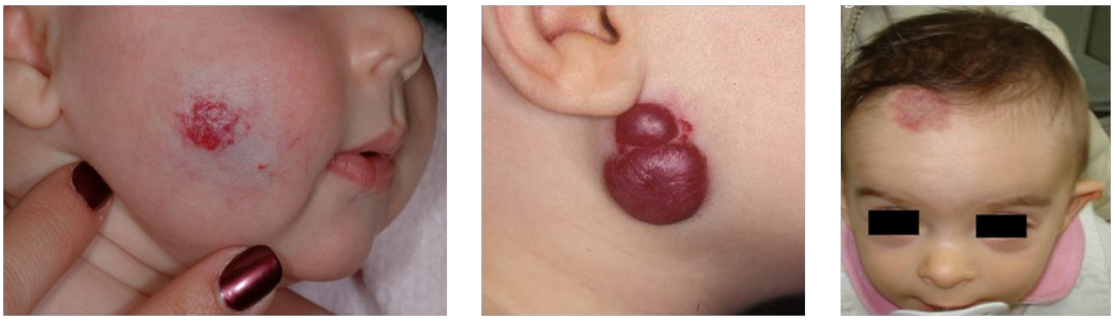

Figure 1. Examples of hemangiomas on the head and neck.

Timely recognition and therapy of those hemangiomas that will cause complications are essential to minimize or eliminate long-term sequelae. We propose to use in our study the non-invasive Optical Coherence Tomography (OCT) imaging technique. To the best of our knowledge, OCT has not yet been applied for *in vivo* diagnosis of hemangioma, only for imaging [3].

The challenges of this approach lie in the ability to identify pertinent markers of the disease, to achieve a sufficient imaging depth with sufficient contrast. Imaging of microvasculature network and flow are useful for the diagnosis, since vascular tumors exhibit abnormal vessel grow.

2. Material and methods

OCT is a high-resolution optical imaging technique that performs depth-resolved microscopy of tissue based on the principle of low-coherence interferometry [4]. The sample is illuminated with a broadband low-coherence source such as an electroluminescent diode (LED), a laser, or even an halogen, at wavelengths between 700 nm and 1300 nm. The detector receives the light backscattered by the microscopic features of the sample. The depth information on the signal is then given by the interferences produced in combination with a reference arm.

Since its development in the early 1990s OCT is mainly used in ophthalmology, but it is also a promising new method for investigation of skin morphology [5-6]. Its diagnosis ability has already been proven for non-melanoma skin cancers [7-8]. Since OCT imaging is performed in real time, in a non-invasive way and with no side effects, it is thus a well-suited tool for *in vivo* disease monitoring.

OCT provides two-dimensional images with axial and transverse resolutions of about 5 to 20 micrometers, and a maximum detection depth of a few millimeters. The image acquisition is performed in real time, in a non-invasive way and with no side effects.

Furthermore, additional information such as the tissue refractive index n or optical attenuation coefficient (OAC) can be extracted from the raw backscattering OCT images [9], as well as flow measurement v_z using the Doppler effect [10].

Indeed, the intensity of the OCT signal on the detector can be written as:

$$I = S(\lambda)\left[R_r + R_S + \sqrt{R_r R_S}\,\mathrm{Re}\left\{ \exp\left(-i\frac{2\pi}{\lambda} 2n[\Delta z + v_z t] \right) \right\} \right]$$

where S is the spectrum, R_R the reflectivity of the reference mirror, R_S being the reflectivity map of the sample, Δz the optical path length difference between the two arms, i.e. the depth, and v_z the velocity of moving sample.

3. Results

We used a commercial swept-source OCT system from Thorlabs (OCS1300SS) operating at a central wavelength of 1300nm, with axial and transversal resolutions of 9 and 25 micrometers. Frame rate was 25 fps for images of 512x512 pixels and 3x3 mm.

A pilot study was conducted with a patient with a port wine lesion (PWS, Port Wine Stain) on the right side of the face (figure 2), after approval of the ethics committee. Images obtained on healthy tissue and lesions are shown on figure 2.

The OCT images of healthy skin show the different skin layers: the stratum corneum, epidermis and dermis, without special structures and vessels. On the contrary, the images of the lesion reveal empty structures that can be vessels or cavernous structures. The use of the Doppler effect allows to extract the blood flow information within the vessels and distinguish between blood vessels and empty cavernous structures.

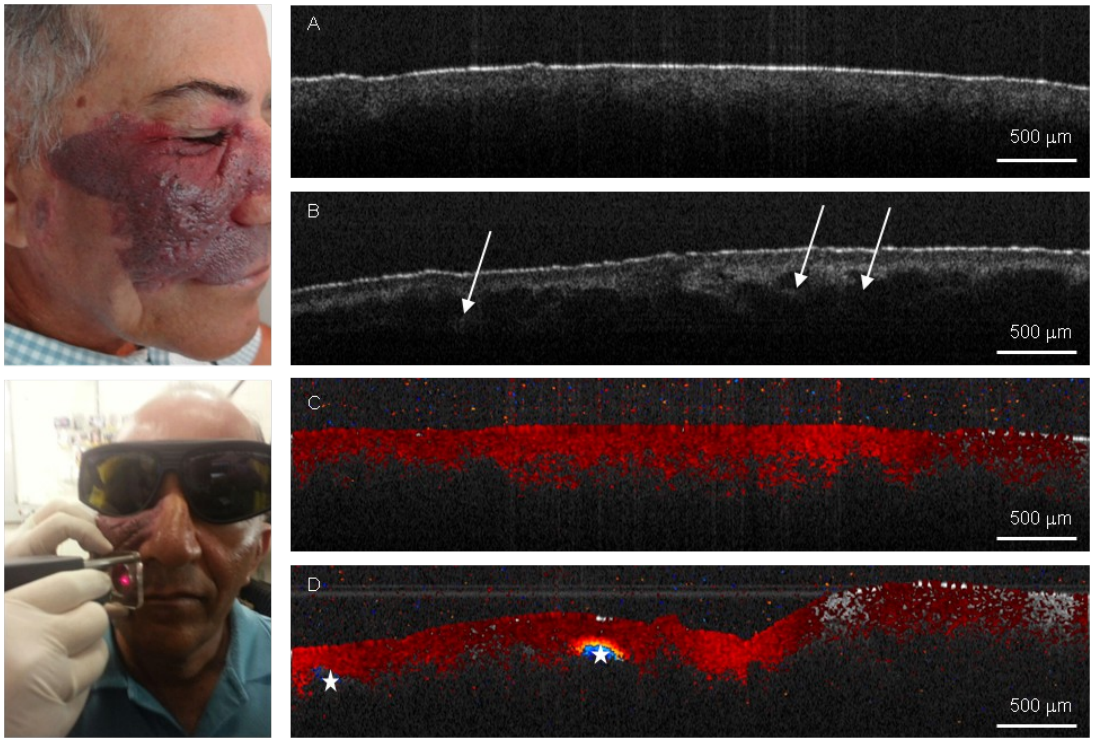

Figure 2. Left : patient with PWS lesion. Right : OCT images on healthy skin (A) and lesion (B) with vessels or cavernous structures (arrows). Doppler OCT images on healthy skin (C) and lesion (D) showing high blood flow vessels (stars).

Figure 3 shows Doppler OCT image on different areas of the lesion. The vessel diameters were found to be between 30 and 500 micrometers at depths between 150 and 500 micrometers. The blood flow information is qualitative but allows for visualization of low blood flow and high blood flow vessels (crosses and stars on the figure). In addition to OCT images, the Doppler modality allows for distinguishing between vessels with a blood flow and empty cavernous structures that could come from the abnormal anarchic growth of vessels.

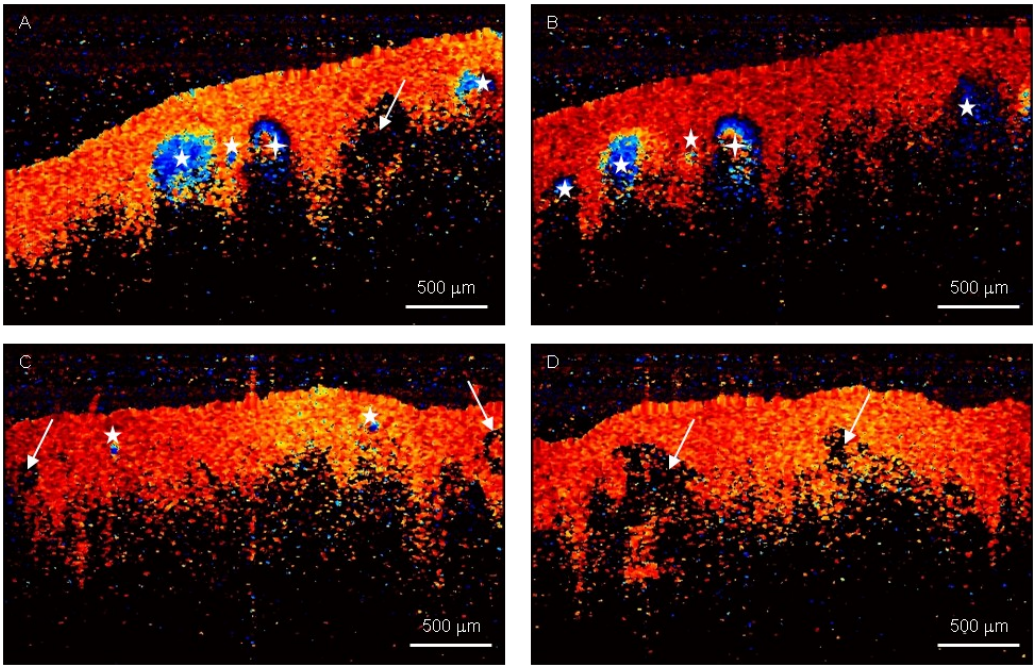

Figure 3. Doppler OCT images on 4 areas of the lesions. The stars show vessels of low blood flow that can have a large diameter (A)(B) of small diameter (B)(C). The crosses show vessels of high blood flow (A)(B). The arrows show cavernous structures (A)(C)(D).

4. Conclusion

Our findings in terms of density, size and depths of the blood vessels are consistent with previous literature on the subject [11]. The Doppler OCT imaging allows the diagnosis between areas of healthy skin and vascular lesions.

Our next step is to set up the clinical imaging protocol to test this modality on a first group of 10 patients from the IMIP hospital in Recife, Brazil. Ultimately we will compare the clinical diagnosis made with OCT with standard diagnosis (eye examination, histopathology) for an overall assessment of the potential and limitations of OCT in the diagnosis of vascular lesions.

5. References

[1] C. Kilcline and I. J. Frieden, “Infantile hemangiomas: how common are they? A systematic review of the medical literature.,” *Pediatr. Dermatol.*, vol. 25, no. 2, pp. 168–73, 2008.

[2] T. S. Chen, L. F. Eichenfield, and S. F. Friedlander, “Infantile hemangiomas: an update on pathogenesis and therapy.,” *Pediatrics*, vol. 131, no. 1, pp. 99–108, Jan. 2013.

[3] Aneesh Alex, J. Weingast, B. Hofer, M. Eibl, M. Binder, H. Pehamberger, W. Drexler, and B. Považay, “3D optical coherence tomography for clinical diagnosis of nonmelanoma skin cancers,” *Imaging Med.*, vol. 3, no. 6, pp. 653–674, 2011.

[4] D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, W. G. Stinson, W. Chang, M. R. Hee, T. Flotire, K. Gregory, C. A. Puliafito, and J. G. Fujimoto, “Optical Coherence Tomography,” *Science (80-.).*, vol. 254, pp. 1178–1181, 1991.

[5] J. Welzel, “Optical coherence tomography in dermatology : a review,” *Ski. Res. Technol.*, vol. 7, pp. 1–9, 2001.

[6] N. D. Gladkova, G. A. Petrova, N. K. Nikulin, S. G. Radenska-Lopovok, L. B. Snopova, Y. P. Chumakov, V. A. Nasonova, V. M. Gelikonov, G. V. Gelikonov, R. V. Kuranov, A. M. Sergeev, and F. I. Feldchtein, “In vivo optical coherence tomography imaging of human skin: norm and pathology,” *Ski. Res. Technol.*, vol. 6, no. 1, pp. 6–16, 2000.

[7] V. R. Korde, G. T. Bonnema, W. Xu, C. Krishnamurthy, J. Ranger-Moore, K. Saboda, L. D. Slayton, S. J. Salasche, J. a Warneke, D. S. Alberts, and J. K. Barton, “Using optical coherence tomography to evaluate skin sun damage and precancer.,” *Lasers Surg. Med.*, vol. 39, no. 9, pp. 687–95, Oct. 2007.

[8] P. Wilder-Smith, W.-G. Jung, M. Brenner, K. Osann, H. Beydoun, D. Messadi, and Z. Chen, “In vivo optical coherence tomography for the diagnosis of oral malignancy.,” *Lasers Surg. Med.*, vol. 35, no. 4, pp. 269–75, Jan. 2004.

[9] D. J. Faber, F. J. van der Meer, M. C. G. Aalders, and T. G. van Leeuwen, “Quantitative measurement of attenuation coefficients of weakly scattering media using optical coherence tomography,” *Opt. Express*, vol. 12, no. 19, p. 4353, 2004.

[10] H. C. Hendargo, R. P. McNabb, A.-H. Dhalla, N. Shepherd, and J. a Izatt, “Doppler velocity detection limitations in spectrometer-based versus swept-source optical coherence tomography.,” *Biomed. Opt. Express*, vol. 2, no. 8, pp. 2175–88, Aug. 2011.

[11] Shiyong Zhao ; Ying Gu ; Ping Xue ; Jin Guo ; Tingmei Shen, et al."Imaging port wine stains by fiber optical coherence tomography", J. Biomed. Opt. 15(3), 036020 (June 15, 2010).