High Resolution Optical Doppler Tomography for *in vivo* Blood Flow Dynamics with Pharmacological Intervention

Cheng-Jen Chang* Zhong-Ping Chen[1]

Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Taipei, Taiwan, 105, ROC
[1]*Beckman Laser Institute, University of California Irvine, Irvine, CA, U.S.A.*

Received 2 July 2003; Accepted 10 Aug 2003

Abstract

High spatial resolution noninvasive techniques for in vivo blood flow imaging are currently not available as a diagnostic tool in clinical medicine. Such techniques could have a significant impact for biomedical research and clinical diagnosis. The rationale for using Optical Doppler Tomography (ODT) to characterize the underlying microvasculature is that the technique will be able to probe user-specified discrete spatial locations with high spatial resolution. The objective of our research is to use a noninvasive tomographic imaging technique with high spatial resolution (2-15 μm) to characterize and monitor fluid flow and microvasculature in highly scattered biological tissues at user-specified discrete locations. ODT combines Laser Doppler Flowmetry (LDF) with optical coherence tomography (OCT) to obtain high-resolution tomographic velocity and structural images of static and moving constituents biological tissue with high light scattering properties. ODT demonstrates the ability to simultaneously record structure and velocity in images. We present ODT images of structure and velocity using in vivo blood flow in the Chick Chorioallantoic Membrane (CAM). ODT images were also recorded before and after topical application of nitroglycerin. ODT images of in vivo CAM blood flow demonstrate that the magnitude of blood flow velocity at the center of the vein is maximal and that it decreases monotonically towards the peripheral wall. The arterial wall can be clearly identified by its dilatation after the application of nitroglycerin. Peak blood flow velocity at the center of the artery increased from 3000 to 4000 μm/s after nitroglycerine application. Dilatation of the vein due to nitroglycerine is observed in both the structure and velocity at the center of the vein. It decreased from 2000 to 1000 μm/s after nitroglycerin application. In conclusion, in our in vivo studies on CAM model vasculatures, the application of ODT to characterize and image blood flow with high spatial resolution at discrete user-specified locations in biological tissues with high light scattering properties is feasible.

Keywords: Optical doppler tomography, Laser doppler flowmetry, Optical coherence tomography, Microvasculature

Introduction

Noninvasive techniques for imaging in vivo blood flow are of great value for biomedical research and clinical diagnostics [1]. The ideal microvascular imaging technique must fulfill several requirements: a) probe the underlying microcirculation at a user-specified depth in both superficial and deep layers; b) distinguish arterial from venous flow; c) detect blood flow changes rapidly; and d) be safe, noninvasive, reliable, and reproducible. Numerous approaches have been investigated including angiography, electromagnetic flowmetry, and magnetic resonance imaging (MRI)[2]. All of these techniques have shown limited utility for tomographic imaging of the microcirculation. More recent approaches have incorporated the Doppler effect [3, 4].

Doppler ultrasound imaging technique uses the principle that the frequency of ultrasonic waves are backscattered by moving red blood cells (RBC) [3]. In addition to being noninvasive, the chief advantage of the Doppler ultrasound technique is it's ability to record images of the heart and large diameter blood vessels (e.g.,>1 mm). However, the relatively long acoustic wavelengths required for deep tissue penetration limit spatial resolution to approximately 200 μm.

Laser Doppler Flowmetry (LDF) was first described in the 1960's by Yeh and Cummins [5]. However, it was not until 1972 that the first blood flow measurement using LDF was demonstrated [6]. LDF uses a single optical frequency which provides a highly coherent light incidence entering the tissue. A second fiber collects the backscattered light; two variables are recorded from this information. One is the velocity of the blood flow, which detected by measuring the movement of the RBC. The other interpretation recognizes static constituents of the biotissue. Light scattered exclusively by static constituents has no frequency change. Detection of the Doppler shift is

* Corresponding author: Cheng-Jen Chang
Tel: +886-2-27135211 ext.3502; Fax: +886-2-25140600
E-mail: chengjen@adm.cgmh.org.tw