A Single Doppler Shift of Laser Doppler for Measured Average Velocity

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Received: September 15, 2012 / Accepted: October 06, 2012 / Published: April 25, 2013.

Abstract: According test the results from samples of clinically normal for ages(20-59) and diabetes mellitusfor measure of blood concentration and resolved velocity by a single shift of laser Doppler flowmetry based on illuminated laser beam on the foot has been reported in this paper of patient safety and noninvasively. The main research to arrive a simple method noninvasive and get more information about the resolved velocity to diagnose the nature of disorder blood flow for different person by using low power laser source, coherent light without thermal effect upon living tissue.

Key words: Laser Doppler flowmetry, singleshift, RBC concentration, perfusion.

1. Introduction

Technique is based on measuring the Doppler shift induced by moving red cell, a noninvasive diagnostic method to measure blood flow in tissue. The blood cells to the illuminating coherent light.

The principle that is the basis for laser Doppler flowmetry (LDF) was first demonstrated by Forrester, et al. in 1955 [1], before the first working laser was presented. The theory was foremost developed by Forrester and extended by Cummins, et al. [2]. Laser Doppler perfusion monitoring was presented in 1989 [3], by Nilsson, et al. [4].

Until the beginning of the 1990s [5, 6], most of the improvements made in the field of LDF were foremost related to the hardware, including the development of laser Doppler perfusion imaging (LDPI). Since then, many of the improvements involve the signal analysis. For further references, a comprehensive review about methodological developments in LDF has recently been published by

Rajan, et al. at the Twenty group [7]. another method measurement of tissue blood flow provides essential contribution to the diagnosis of diseases which causes in impaired blood flow by non-invasive capillary blood flow measurement laser speckle and laser Doppler [8].

In this paper the laser Doppler flowmetry established a new method to measure blood flow on the dorsal plus in the foot to normal subject and diabetic mellitus patients results have been compared.

2. Theories

When light is scattered by a moving object it will be frequency shifted depending on the movement of the object, the direction of the incoming light and the direction of the scattered light with velocity v (m/s) . The angular frequency shift, f_D will then be [9]:

$$f_D = (-\text{velocity of RBC} \cdot \text{Scattering vector}) \cdot v \cdot q = -2v/\lambda \sin\theta/2 \cos\varphi \quad (1)$$

where, v is the velocity vector of the moving object in the plane of scattering, the scattering vector q is the difference between the wave vectors k_i and k_s ($|k| =$

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$1/\lambda$) of the incident and scattered light wave, respectively, λ is the wavelength, θ is the scattering angle, and φ is the angle between q and v presented. The light wave incident to the particle has a frequency f_i and a wavelength $\lambda_i = 1/k_i = c/f_i$, where $c = c_0/n$ is the speed of light in the tissue with refractive index n .

The frequency shift f_D is the difference between the frequency of the incident and scattered light waves, i.e. $f_i = c/\lambda_i$ and $f_s = c/\lambda_s$, respectively.

$$f_D = f_i - f_s = c \left(\frac{1}{\lambda_i} - \frac{1}{\lambda_s} \right) \quad (2)$$

where the nominator is removed in the last step since $v \ll c$. This observation also leads to $\lambda_i \approx \lambda_s$ and consequently $k_i \approx k_s$. This Doppler shift is dependent on the velocity of the moving red blood cells according equation:

$$f_D = \frac{2nv}{\lambda_0} \times \sin\theta \cos\varphi \quad (3)$$

where, v is the velocity of the moving red blood cell, n is the refractive index of the medium with a diode laser ($\lambda = 785$ nm), and the refractive index $n = 1.4$ of skin tissue. according this equation can calculate the single Doppler shift by the for all different subjects and the velocity of blood cell.

$$v = f_D \times \frac{\lambda_i}{2n \sin\theta \cos\varphi} \quad (4)$$

Subst. Eq. (1) into Eq. (3) can get as the resolved velocity.

To calculation of the RBC concentration and perfusion estimates Larsson has explained the expressions for the RBC concentration and perfusion estimates in the frequency domain. An alternative the time domain is given by Nilsson, et al. [10].

Let start by establishing a relationship between the red blood cell concentration C_{RBC} and the fraction of Doppler-shifted photons f . A simple expiration by Beer-Lambert's law where the fraction non shifted

photons can be approximated to Ref. [11]:

$$1-f \approx e^{-l_p(RBC) \mu(RBCs)} \quad (5)$$

where, l_p is the photon path length in tissue 0.5 mm and μ_{sRBC} is the scattering coefficient for blood 222.

Perfusion = Concentration of moving blood cells $\times$ Velocity of these cells.

Effect of glucose on absorption and scattering properties of Tissue-Glucose can affect the measured transmitted or reflected signal by absorption and scattering of light at 785 nm wavelength.

Attenuation of light in tissue is described, according to light transport theory, by the effective attenuation coefficient μ_{eff} , which is explain in the following equation [12]:

$$\mu_{eff} = \sqrt{3\mu_a(\mu_a + \mu_s')} \\ = \sqrt{3\mu_a[\mu_a + \mu_s(1-g)]} \quad (6)$$

Fredriksson [13] put the model, this model consists of three layers; the bloodless epidermis layer with variable thickness and two dermis layers where the first layer is 0.5 mm thick and the second has an infinite thickness. The later research consider the structure of biological tissue is complex which is difficult to satisfy Mie calculation of phase function instead of used approximate empirical phase function (Table 1) appears the optical for laser diode 785nm. The most common phase function in bio-optics is the Henyey-Greenstein HG phase with different factors. To research in this field [9].

So depth Penetration sensitivity $1/\mu_{eff}$ is 0.5163977 mm. The thickness (same scaling factor for all layers) and blood tissue fractions (concentrations) at three different flow velocities could be altered from the standard model.

All velocity components were evenly distributed between 0 and twice the mean velocity (0.3, 2.0).

Table 1 Optical properties of the tissue model.

Tissue type	n (-)	μ_a (mm ⁻¹)	μ_s' (mm ⁻¹)	μ_s (mm ⁻¹)	g (-)
Epidermis	1.4	0.4	3.5	23	0.85
Dermis	1.4	0.1	2.0	13	0.85
Subcutis	1.4	0.1	2.0	13	0.85
Blood	1.4	0.5	2.0	222	0.991

Fig. 1 Measuring arrangement for blood flow in microcirculation. A diode laser irradiates the skin and the remitted light is sampled by a photodiode without any optics.

3. Material and Method

This study has been carried by research of the subject at different men ages, subjects having measurements (height, weight and some biochemical tests like blood glucose and hypertension).

A new method to laser Doppler flowmetry monitoring (LDFM) (Fig. 1) operation consist three parts: The light from a laser source (diode laser 785 nm, 30 mw) detector (the ocean optical spectrometer) and computer. When the light source is transmitted to the skin area 12.56 mm². A portion of the back-scattered radiation is gathered by afferent optical fibers and detected in an operation set-up.

The system operate and record the incident wavelength output by software analysis on the screen at fitting line after the beak appearance and neglect the noises. Save results writes an ASCII file containing a list of the lines in the HR4000 software. All the test happened at room temperature of 25 ± 1 °C.

Subjects in the site position on the sitting of chair after get weight and height, put the foot on the position without movement and 0.5 min for acclimatization.

4. Results and Discussion

Initial experiment has carried on through the part of illuminated volume, this is hemisphere of radius about 2 mm incident on foot with wavelength 785 nm based on

small Doppler shift for different subject is incident frequency 3.8216×10^{14} . The backscattered light is shifted of single wavelength, i.e., frequency according the relation $f = c/\lambda$, namely the original wave frequency and the Doppler shifted frequencies ($f_D \times 10^{11}$).

(a)

(b)

Fig. 2 Show the peak of incidence light and scattering light for (a) normal subject ages 24 and (b) Diabetes patients (DM) ages 24 year patient the opposite side from clinically normal.

Table 2 Subject demographics for Clinically normal.

No.	Gender	Age (year)	Height (m)	Weight (kg)	BMI (Kg/m ²)	$fd \times 10^{11}$ (Hz)	V (mm/s)	CRBC $\times 10^{-6}$	Perfusion (PU) = $\mu\text{m/s}$
1	Male	20	1.801	61.2	18.8679	6.6018	1.2008	15.32835	0.01840628
2	Female	21	1.65	53.5	19.65106	6.6018	1.2008	15.32835	0.01840628
3	Male	22	1.825	90.7	27.23212	6.6018	1.2008	15.32835	0.01840628
4	Male	23	1.803	80.6	24.7938	3.5727	0.6482	8.385799	0.0054356
5	Male	24	1.691	82.4	28.8164	3.8171	0.69428	8.959769	0.00622
6	Male	25	1.73	88.9	29.7036	0	0	0	0
7	Female	27	1.535	55.2	23.4273	3.3282	0.60535	7.811663	0.00472879
8	Male	28	1.77	67	21.3859	2.9782	0.54239	6.989918	0.00379126
9	Female	29	1.47	55.6	25.73	3.5727	0.6482	8.385799	0.0054356
10	Male	30	1.7	72.9	25.2249	3.5727	0.6482	8.385799	0.0054356
11	Male	33	1.79	74.8	23.3451	3.5727	0.6482	8.385799	0.0054356
12	Male	34	1.69	78	27.31	3.5727	0.6482	8.385799	0.0054356
13	Male	35	1.772	105.9	33.7263	6.6018	1.2008	15.32835	0.01840628
14	Male	36	1.86	95.5	27.6043	2.9782	0.54239	6.989918	0.00379126
15	Male	37	1.66	80	29.03178	6.3577	0.8376	14.92814	0.012508
16	Female	38	1.62	91.3	34.7889	3.5727	0.6482	8.385799	0.0054356
17	Female	40	1.68	96.4	34.1553	3.3282	0.60535	7.811663	0.00472879
18	Male	41	1.81	96.3	29.3947	3.5727	0.6482	8.385799	0.0054356
19	Male	42	1.77	106.3	33.93	3.5727	0.6482	8.385799	0.0054356
20	Male	43	1.763	74.9	24.09778	3.5727	0.6482	8.385799	0.0054356
21	Male	52	1.68	76.7	27.17545	0.4891	0.089028	8.385799	0.000102172
22	Male	55	1.69	98.8	29.00519	2.9782	0.54239	1.14764	0.00379126
23	Male	59	1.7	81.2	28.09688	3.3282	0.6535	6.989918	0.00510487

Table 3 Subject demographics for DM diseased subjects.

NO.	Gender	Age (year)	Height (m)	Weight (kg)	BMI (Kg/m ²)	$fd \times 10^{11}$ (Hz)	V (mm/s)	CRBC $\times 10^{-6}$	Perfusion (PU) = $\mu\text{m/s}$	glucose mg/dl	duration time
1	Female	20	1.56	55	22.6003	-2.679	-0.4888	-6.28417	0.003072	133	1 year
2	Female	21	1.5	57	25.3333	-2.6795	-0.4888	-6.28417	0.003072	130	2 year
3	Male	23	1.73	89.2	29.8039	-1.9065	-0.3472	-4.47186	0.0015577	126	4 month
4	Male	24	1.746	70	22.962	-2.6873	-0.3546	-6.3024	0.000107	265	2 year
5	Female	25	1.503	120	53.12063	-5.517	-0.7292	-12.9341	0.009436	367	4 year
6	Male	26	1.68	71.8	25.4393	-3.9076	-0.7121	-9.0045	0.006412	278	8 year
7	Female	28	1.6	58	22.65625	-3.2274	-0.4577	-7.24663	0.003085	160	20 year
8	Female	28	1.603	66.1	25.72375	-3.1241	-0.5587	-7.32649	0.0040938	168	10 year
9	Male	32	1.712	87.2	29.75150	-3.609	-0.6454	-8.463	0.0054625	220	14 year
10	Male	35	1.7	74.6	25.81314	-3.5596	-0.6366	-8.34737	0.0053144	189	10 year
11	Male	37	1.9	105	29.0858	-3.9488	-0.5218	-9.25971	0.004832	231	4 year
12	Male	38	1.735	100	33.22010	-3.1241	-0.412	-7.32647	0.003025	317	8 year
13	Male	40	1.77	85.3	27.2271t	-2.7780	-0.3671	-6.51516	0.002398	132	4 year
14	Female	41	1.53	74.5	31.82536	-2.635	-0.4714	-6.18218	0.0029146	181	12 year
15	Male	42	1.599	72	28.16018	-2.586	-0.4625	-6.06492	0.0025	328	8 year
16	Female	43	1.632	87	32.66472	-3.1241	-0.5587	-7.32649	0.0040938	164	5 year
17	Male	45	1.87	97.4	27.85324	-7.8364	-1.0337	-1.83663	0.0189795	389	0.25 year
18	Female	46	1.714	79.1	26.92494	-3.075	-0.5499	-7.32584	0.0040291	245	13 year
19	Male	47	1.904	77.4	21.35045	-2.6359	-0.3483	-6.18218	0.0021537	238	5 year
20	Female	50	1.703	78.4	27.03253	-1.266	-0.1673	-2.96966	0.0004968	136	15 year
21	Male	51	1.735	100	33.22010	-3.4607	-0.457	-8.115	0.0037118	111	5 year
22	Female	53	1.702	88.9	30.68894	-2.6359	-0.4714	-6.18218	0.0029146	170	17 year
23	Male	54	1.713	66.7	22.73061	-1.122	-0.2935	-2.63193	0.0007727	324	12 year
24	Male	55	1.582	64.5	25.77191	-3.316	-0.6020	-7.89353	0.0047521	361	14 year
25	Male	57	1.69	77.9	27.27495	-3.0731	-0.4059	-7.20693	0.0029253	208	4 year
26	Female	58	1.405	75	37.99343	-2.8800	-0.5151	-6.80920	0.0035075	167	20 year
27	Female	59	1.81	87.3	26.64753	-2.586	-0.3793	-6.04958	0.002072	318	23 year

(a)

(b)

(c)

Fig. 3 Explain the relation (a) average blood flow (b) Concentration red blood cell (c) perfusion with frequency Doppler shift for normal subject.

Fig. 2 shows the peak of incidence light and scattering light for different subjects.

The LDFM for diseased subject resolved velocities < 1 mm/s. the lower velocities of all diseases and concentration red blood cell but higher perfusion about 0.10409 for high level glucose. The increased blood flow occurs in vessels with a velocity above 1mm/s. This results is satisfy with Fredriksson, et al. [14].

The perfusion of diseases is higher than the clinically normal but the concentration of red blood cell is lower than normal subjects. A significantly total

(a)

(b)

(c)

Fig. 4 Explain the relation (a) average blood flow (b) Concentration red blood cell (c) perfusion with frequency Doppler shift for diabetes Mellitus subjects.

perfusion $0.4 < v < 1.2008$. The sign (–) indicate the resolved velocity opposite direction to the normal subject. Total perfusion is higher unless the disease with insulin is lower perfusion.

5. Conclusions

The perfusion increases occur in the hyperglycemia and high level glucose for patients so that increases the velocity to baseline data of normal subject indicated a distribution of flow to higher velocity region of capillaries vessels regions compare to the

mean blood velocity for various types of vessels [13]. All subjects microvascular abnormality has also been increased flow through the arteriovenous shunts resulting in reduced capillary flow less than 0.3 mm/s in Table 2 for normal subject and Table 3 for diseases. While differences in blood flow between DM and controls using laser Doppler flowmetry studies have reported a lower blood flow in diabetes mellitus at different glucose compared with controls indicates the opposite scattering causes in all states.

The perfusion measure is divided into two region $v < 1$ mm/s, $v > 1$ mm/s. the method presented is based on a single Doppler shift to measured spectra at the same separation between source-detector. The diabetes mellitus indicates to distribution of velocities appears to distribution of level glucose the decreases velocity causes increasing perfusion significant difference between the DM patient and normal subjects is found in the two lowest velocity regions.

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