WAVELET-BASED FLUCTUATION ANALYSIS OF LASER DOPPLER BLOOD FLUX ON RENAL CORTEX IN RATS

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Abstract- **Fluctuations of peripheral blood flux are related to its physiological or pathological condition. The oscillations of skin and muscle are well studied. Due to hard to install the probe, fewer studies about the oscillation of fluctuations of peripheral blood flux on internal organ are investigated. In this study, using a fast Laser-Doppler flowmetry (LDF) with a signal fiber probe, we measured the renal cortical flux (RCF) and abdominal aortic blood pressure (AABP) simultaneously in rats. With a continuous wavelet transform, we analyzed the fluctuations of RCF and estimate their weights on RCF.**
***Keywords*– Wavelet, Laser Doppler Flowmetry, Renal Cortex, Blood Flux**

I. INTRODUCTION

Studies of the human skin microvascular oscillations had been done by Laser-Doppler flowmetry (LDF) in the past two decades[1,2,3]. They showed five distinct frequency ranges of fluctuation due to the pulsatile cardiac cycle (about 0.6~2.3Hz), the respiratory-dependent oscillation (about 0.2~0.6Hz), the intrinsic myogenic activity of smooth muscle in vessels (about 0.06~0.2Hz), the arteriolar vasomotion (about 0.02~0.06Hz) and metabolic activity (about 0.009~0.02Hz). Some similar studies in estimation the microvascular oscillations of muscle also shown a similar dynamics with the above researches [4,5].

However, only a few studies investigated the microvascular oscillations of internal organs by LDF [6] or by other methods [7]. We had developed a fast LDF method to estimate the pulsatile-related oscillation (0.5 ~20Hz) on the renal cortex of rats [8]. With this method, we can also estimate the wide range spectrum (0.01~10Hz) of renal cortical flux oscillation.

In this study, the object is to develop a methodology in order to estimate the wide range oscillation (0.01~10Hz) of microcircular flux on the renal cortex. We use a LDF with a signal fiber probe to measure the renal cortical flux in rats and analyze the fluctuations with time by a continuous wavelet transform (CWT).

II. METHODOLOGY

Animal Preparation and Experimental Setup

3 male WKY rats, weighting from 250 to 350 g, were anesthetized with Urethane (300mg/kg, ip). The rat was then placed on an operation table with a heated pad to keep the body temperature. Anesthesia was maintained by additional doses of anesthetics as required. The polyethylene tube (PE 10, Becton-Dickinson, USA) was inserted from the iliac artery into the abdominal aorta of the rat with a catheter-tip pressure transducer (P10EZ, Viggo-Spectramed, USA) to measure AABP.

Laser Doppler Flowmetry (MBF3, Moor Instruments Ltd., England) was used for the measurement; its time constant was set to 0.05 second and its cut-off frequency was 14.9 kHz. MBF3 samples the analogue signal with a 40Hz sampling rate and then converts it into analogue output. An optical fiber probe (P10M+P17, plastic fiber 500μm O.D., Moor Instruments Ltd.) was calibrated by the calibration flux standard (Moor Instruments Ltd.) to ensure its stability and performance.

Experiments and Data acquisition

The left kidney was exposed from the dorsal side, and fixed with sterilized gauze sponges. The fatty capsule was separated carefully to avoid bleeding, and the surface of the kidney received an infusion of 37°C normal saline to keep it from drying during the experiments.

The optical fiber probe was gently touched vertically to the surface of the renal cortex to avoid artifacts introduced by respiration or other inner movements. The motion artifact caused by the respiration can be easily detected; the period is about 3-5 times that of the heartbeat. Proper installation of the probe and good care of the animals during the experiments can reduce the artifact. Aortic blood pressure, both diastolic and systolic, was monitored during the experiments.

The RCF signal was recorded from the analogue output of MBF3. Both the AABP and RCF signals were connected to a simultaneous sample & hold card AX753 (AXIOM Technology Co., LTD. Taiwan, R.O.C.) and then to an A/D converter card AX5621 (AXIOM Technology) with 20Hz sampling rate. Both signals were sampled simultaneously and synchronously. There were 5 different sites on the surface of renal cortex measured within one hour to avoid physiological change in each rat; each site kept at least 1 cm apart the other and the positions were chosen where there are no visible vessels. In each measurement, we acquired a 120 second-long data sequence.

Data analysis and Statistics

A continuous wavelet transform with Morlet wavelet was used to analyze the measured data. A short time Fourier Transform (STFT) was also employed to be reference. The statistic results of the dominant spectrum peaks were represented by mean±SD.

All the signal processes were performed with MATLAB, IBM-PC version (Math Works, Natick, Mass., U.S.A.).

III. RESULTS

Figure 1 shows one example of CWT. Fig. 1(a) is the one of RCF and fig. 1(b) is the one of AABP. They show that there are some low frequency oscillations on RCF but not on AABP.

Figure 2 is a time average result in one measurement of RCF and AABP using STFT respectively. The heart-rate oscillation is the dominant peak in the spectrum and the

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25OCT2001	N/A	-

Title and Subtitle Wavelet-Based Fluctuation Analysis of Laser Doppler Blood Flux on Renal Cortex in Rats	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Department of Electric Engineering, National Taiwan University, Taipei, Taiwan, R.O.C.	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research Development & Standardization Group (UK) PSC 803 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from the 23rd Annual International conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
3

respiratory as well as low-frequency (below 0.1Hz) oscillations are also existed.

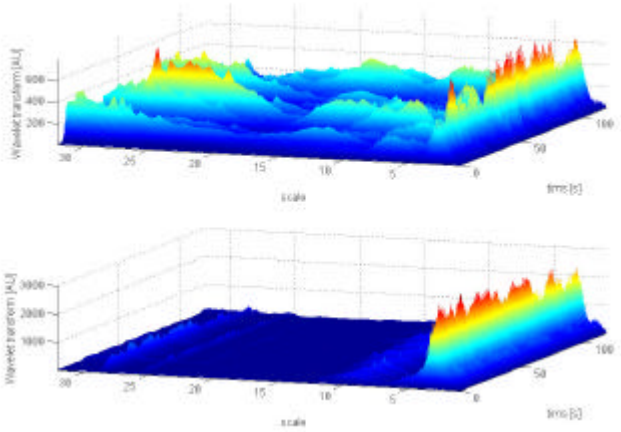

Figure 1. CWT analysis of RCF(above) and AABP(below)

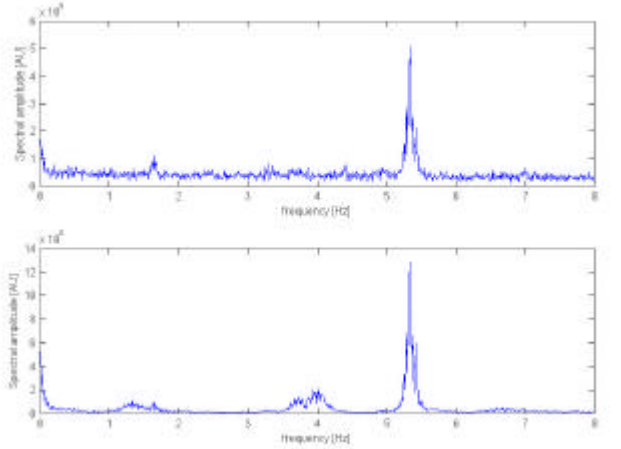

Figure 2. STFT analysis of RCF(above) and AABP(below)

Due to LDF calibration, the absolute values of RCF in different rat could be very diversified. Table 1 statistics the peak values of heart-rate oscillation and low frequency oscillation of RCF as well as AABP, respectively. It shows that, in the 15 measurements, the low frequency oscillation weights less than 67%.

Table 1

Peak values of heart-rate oscillation and low frequency oscillation

(A) Rat1

	Low frequency	Heart rate
RCF	2.38±0.71	8.24±0.71
AABP	6.23±2.25	22.18±2.22

×10^5; n=5

(B) Rat2

	Low frequency	Heart rate
RCF	4.05±0.17	6.95±1.70
AABP	10.56±4.32	22.48±4.32

×10^5; n=5

(C) Rat3

	Low frequency	Heart rate
RCF	4.32±2.22	6.54±0.96
AABP	8.43±4.36	33.05±4.36

×10^5; n=5

IV. Discussion

Short time Fourier Transform was one of the most popular methods to investigate the time-frequency relationship of a time-variant signal. However, with a better time-frequency resolution, we use CWT to analyze our data in the study.

Marcohemodynamics and microhemodynamics have been developed over two decades. One focus on arterial dynamics, and the other studies the behavior of microcirculation. However, there is an interesting distinction between them. Most of marcohemodynamics studies deal with the arterial behaviors in the range nearby the heart rate or on its harmonics; meanwhile, microhemodynamic studies concentrate on the lower frequency (0.01Hz~0.1Hz). The driving force driven by the arterial blood pressure seems to lose its role in its downstream.

In Fig. 1, it shows that only the heart–rated oscillation and the respiratory-oscillatory keep much steady in all times. The heart-rate oscillation seems to be the basal signal as the carry wave in radio signal modulation. In our previous studies [8], through a long time average, most of the low frequency oscillation of RCF would be filtered out except the ones on harmonics of heart rate. At the same time, the respiratory oscillation and a low frequency (below 0.1Hz) are like the modulation signals, oscillating depends on events.

The mammalian arterial blood pressure keeps almost constant from aorta to the range of arterioles; it drops abruptly in the short distances between arterioles and capillaries. Is the lost blood pressure the driving force of the blood flux in peripheral microvascular beds? Or is it just dissipated by the viscous force due to the tiny channels of arterioles and capillary? There is a disjunction in the studies between the arterial blood pressure and the microvascular flux. And, they are questions have to be further clarified.

Our result showed that the oscillation of peripheral blood flux in kidney is much different to the ones in skin or in muscle. Heart-rate oscillation is the key oscillation. It implies that the heart pumping generated pulsatile pressure drives RCF with less peripheral modulation.

V. Conclusion

In summary, this study demonstrates a methodology to investigate the oscillations on RCF. With this methodology, we found that, different to skin or muscle, heart-rate oscillation is the dominant oscillation on RCF in the basal physiological state.

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