Spectral Correlation Study of Skin Blood Flow Oscillation

T. X. Chi and Y. Liu

Abstract Spontaneous rhythmic oscillations in microvessel diameter are known as vasomotion. Vasomotion is the intrinsic property of small arteries and arterioles and is dependent of heartbeat, respiration, or neuronal input. The skin microcirculation is an anastomotic network of vessels with many crucial functions in which the blood flow must be finely regulated and tuned in order to fulfill all the demands of the organism. The laser Doppler Flowmetry (LDF) can be used to measure dynamic changes in skin blood flow over a small area. Traditional Chinese medicine (TCM) considers that there exist acupoints around body which are connected by meridian, and stimulating the acupoint is a typical therapeutic technique in TCM. It was found that stimulating one acupoint could enhance the vasomotion in another acupoint significantly. We argue that the vasomotions in these two acupoints could be correlated to each other. To verify our argument, we used the laser Doppler Flowmetry (LDF) to measure the skin blood flow at two acupoints, and carried out spectral and correlation analyses. It is found that the vasomotions related to myogenic activity are quite strong at acupoints and the correlation is discernable. The vasomotion related to myogenic activity at non-acupoint is much weaker and there is no significant correlation between the acupoint and non-acupoint.

Keywords LDF · Vasomotion · Myogenic

1 Introduction

The spontaneous time-dependent contraction and relaxation of small arteries and arterioles are termed as vasomotion which may have considerable implications in the physiology and pathology of the arterial system. The spectral analysis of human

T. X. Chi (✉) · Y. Liu
Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong, China
e-mail: 15900011r@connect.polyu.hk

Y. Zhou et al. (eds.), *Fluid-Structure-Sound Interactions and Control*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-10-7542-1_42

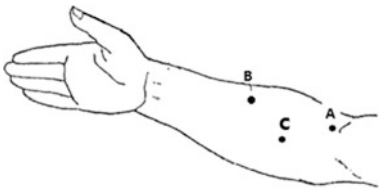

Fig. 1 Two selected acupoints (named Chize (**A**) and Kongzui (**B**)) and one non-acupoint (**C**)

skin blood flow oscillation has revealed five frequency components of vasomotion: the band 0.6–1.8 Hz is due to heart activity, the band 0.2–0.6 Hz is related to respiration, the band 0.06–0.2 Hz is related to myogenic activity, the band 0.02–0.06 Hz is associated to sympathetic activity and the band 0.007–0.02 Hz is more specifically related to endothelial activity [1]. It was found that the vasomotion propagates along arterioles, capillaries and venules in both upstream and downstream directions. Moreover, there is evidence that microcirculation may mirror the vascular function of other parts of the body and the microvascular abnormalities may initiate the pathogenesis sequence in some diseases. In TCM, the acupoints are interrelated to each other, and acupuncturing at one acupoint may affect another acupoint. Several in vivo human studies have found that acupuncturing at one acupoint may increase significantly the myogenic component of flowmotion at another acupoint. To verify whether the vasomotions related to myogenic activity at acupoints are correlated to each other, we selected two acupoints along the same meridian (A and B). In addition, another non-acupoint (point C) is selected as reference (Fig. 1).

2 Materials and Methods

2.1 Measurement Procedure

Two LDF probes were positioned on two selected points. The ambient temperature is set at 23 ± 1 °C in room and sampling rate is 20 Hz equivalent to 0.05 s time interval. Points A−B and Points A−C were measured simultaneously. The measurement time was 20 mins.

2.2 Spectral Analysis

The mainly analytic tools analyzing the LDF signal are usually considered as the linear analysis which include Fast Fourier transform analysis (FFT) and Morlet wavelet analysis. Periodic oscillations of skin blood flow can be quantified directly

by FFT which could reveal the amplitude (energy) of the whole signal at given frequencies. For wavelet analysis, its feature allows us to determine both the dominant modes of blood flow oscillation and how those modes vary in time. For skin blood flow signals, Morlet wavelet analysis breaks down the steady fluctuating time series into its frequency elements and computes the power of signal components in predetermined frequency bands, allowing to measure the amplitude of different flowmotion waves in PU/Hz.

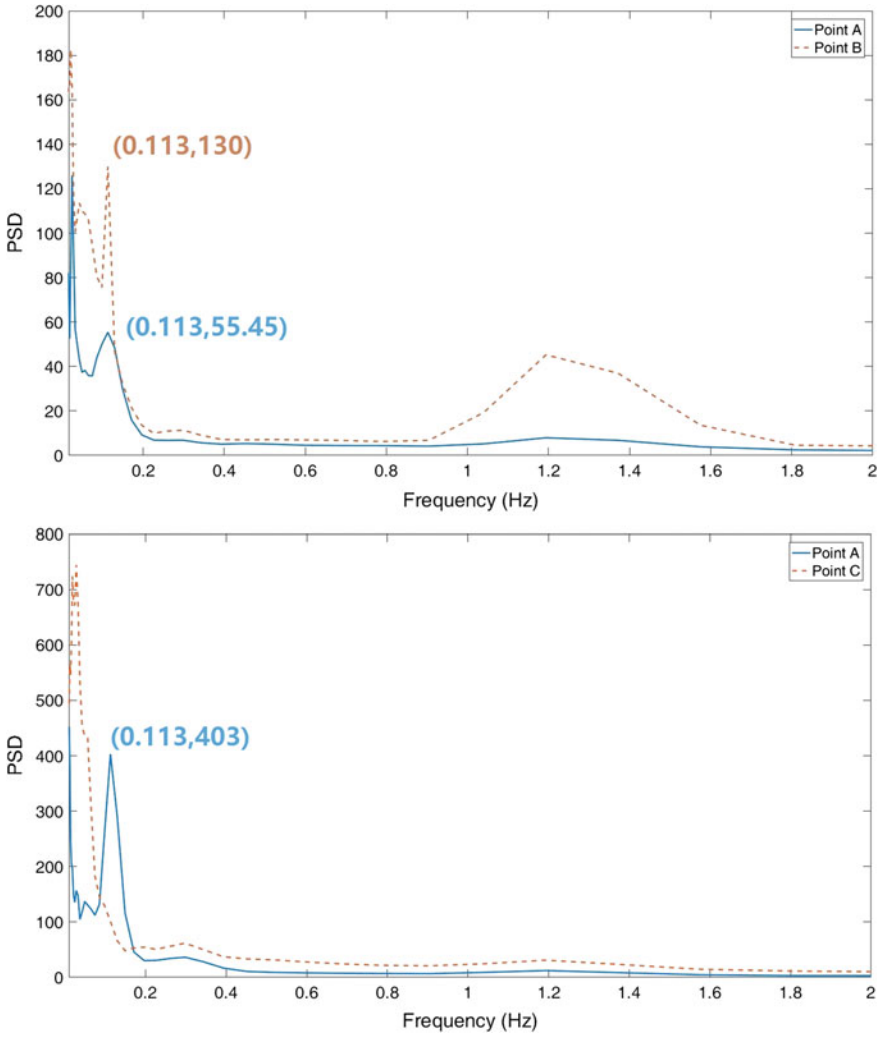

Fig. 2 FFT of Acupoint (**A**),Acupoint (**B**) and Non-acupoint (**C**)

3 Results and Discussion

3.1 FFT and Wavelet Analysis

From FFT analysis, the PSD of acupoint A and B at ~0.1 Hz are dominant on Fig. 2, but not for the non-acupoint C. Thus It could be explained that the skin blood flow oscillation on these two acupoints (A and B) are influenced greatly by the myogenic factor (~0.1 Hz). In addition, all the PSDs of the lower frequency are higher than that of 1 Hz for these three points, indicating the myogenic component

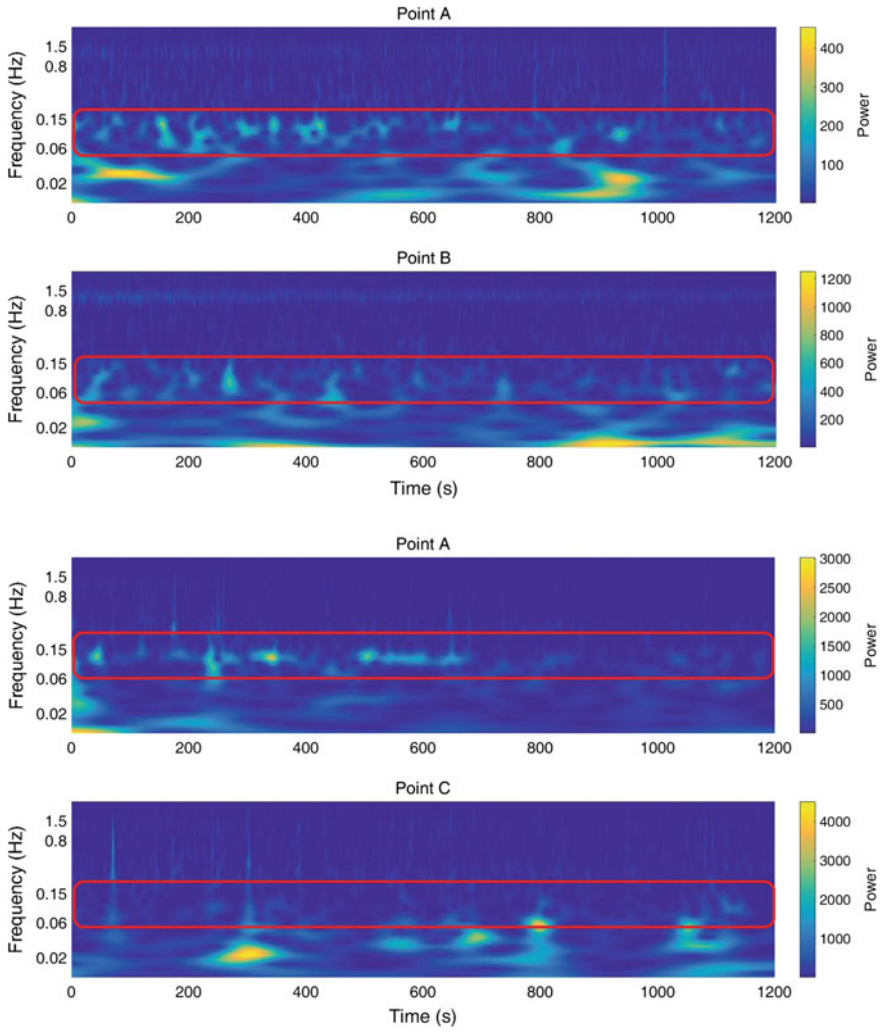

Fig. 3 Morlet Wavelet analysis of Acupoint (**A**) and Non-acupoint (**C**)

of vasomotion is significant. Comparing with the FFT analysis, the wavelet transform does not lose the time-series information of characteristic frequency, and it is obviously that the energy at different frequency varied with time. From wavelet analysis, the Fig. 3 shown that the PSD of acupoint A and B at ~0.1 Hz exhibits periodic behaviour and follows a certain pattern, and the non-acupoint have no significance periodic pattern occurred at ~0.1 Hz. Therefore, the periodic behavior at ~0.1 Hz only exists in acupoints (A and B), and this periodic behavior should follow a certain transmitting direction.

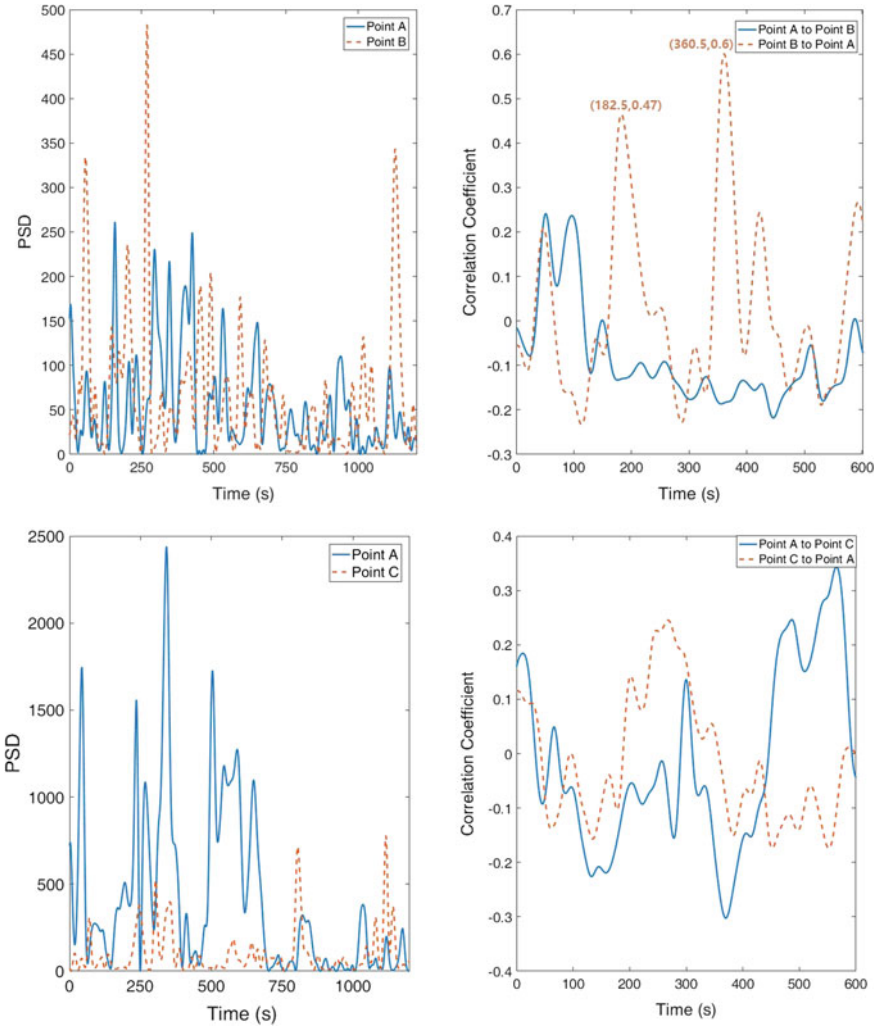

Fig. 4 Extracted PSD from wavelet analysis and phase lag

3.2 *Extracting Characteristic from Wavelet and Correlation Analysis*

Since the PSD at 0.1 Hz in wavelet follows a periodic pattern, if the myogenic vasomotions at acupoints are correlated to each other, the wavelet PSD variations with time should be correlated as well. We extracted the PSD signal at 0.1 Hz from wavelet analyses in Fig. 3, and carried out cross-correlation analysis between these two extracted time series. The PSDs of both acupoints A and B are comparable (Fig. 4), but the PSD of acupoint A is much higher than that of non-acupoint C (Fig. 4). From point A to point B, there is no significant correlation identified; from point B to point A, the maximum correlation can be 0.6 with a phase lag 0.93 π (Fig. 4). Thus, it could be stated that the myogenic factor transmitted from point B to point A. For point A and point C, there is no significant correlation found, indicating the myogenic components in acupoint and non-acupoint are not correlated. Therefore, of the correlation of myogenic related vasomotion only existed between acupoints A and B.

4 Conclusions

The LDF measurement was carried out at acupoint and non-acupoint simultaneously, the spectrum and correlation analyses lead to following conclusion: The myogenic component of vasomotion is dominant in term of PSD; The PSD of myogenic component is much higher in acupoint than that in non-acupoint; There exist correlation of myogenic components between acupoints, but there is no correlation between acupoint and non-acupoint.

Acknowledgements Supports given by HKRGC PolyU 5202/13E and PolyU G-YBG9 are gratefully acknowledged.

Reference

1. Rossi M, Carpi A, Di Maria C et al (2006) Spectral analysis of laser Doppler skin blood flow oscillations in human essential arterial hypertension. Microvasc Res 72(1–2):34–41