A TIME-FREQUENCY APPROACH USING WAVELETS TO STUDY WEEK-TO-WEEK VARIABILITY IN BLOOD FLOW OSCILLATIONS

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INTRODUCTION

Laser Doppler flowmetry has been used extensively to quantify skin perfusion response to compressive loading (1). The study of blood flow responses is confounded by temporal variability in blood flow measurements (2). Several methods have been reported to compensate for temporal variability in baseline blood flow measurements. However, the success of these methods in reducing temporal blood flow variability has been mixed. Spectral analysis has been shown to be useful in isolating the effects of distinct control mechanisms to various stimuli in the microcirculatory system (1). However, the sensitivity of spectral analysis to temporal blood flow variability has not been reported. This study investigated the effectiveness of a wavelet analysis technique in reducing week-to-week variability in blood flow measurements.

METHODS

Ten healthy subjects were brought into the laboratory on three occasions separated by 7±2 days for measurements of baseline and thermally induced maximal sacral blood flow for three consecutive weeks. Blood flow over the sacrum was recorded during 10 minutes of rest to establish baseline flow followed by 15 minutes of incremental heating from 35°C to 45°C. Laserflo Blood Perfusion Monitor 2 (BPM^2, Vasamedics, Eden Praire, MN) and Softip pencil probe (P-435, Vasamedics) were used to measure capillary blood perfusion (ml/min per 100g tissue). A temperature control module (TCO, Vasamedics) with heater probe (P-422, Vasamedics) was used to heat the skin to 45°C to obtain a maximal skin blood flow response. Laser Doppler blood flow was sampled at 20 Hz using a 16-bit data acquisition card (PCI-MIO-16XE, National Instruments, Austin, TX).

Wavelet analysis was used to decompose blood flow signals into frequency components determined to be associated with metabolic (0.008-0.02 Hz), neurogenic (0.02-0.05 Hz), myogenic (0.05-0.15 Hz), respiratory (0.15-0.4 Hz) and cardiac (0.4-2.0 Hz) control mechanisms (1). Analysis methods were used to study relative contributions in each characteristic frequency band to total blood flow (1). The rationale for designation of frequency range for each characteristic frequency band's control mechanism is described in Geyer et al. (1).

Maximal blood flow ratio was defined as the ratio of baseline blood flow to thermally induced maximal blood flow at 45°C. The coefficient of variation (CoV), independent of units of measurements, was used to analyze the impact of inherent skin blood flow variability on various normalization methods by comparing its magnitude between total skin blood flow at baseline, power within each characteristic frequency band at baseline and baseline skin blood flow normalized to the maximal blood flow according to the ratio method.

RESULTS AND DISCUSSION

The CoV for the blood flow signal power in each individual frequency band at baseline (CoV range from 0.08 to 0.15) were smaller than that of blood flow at baseline (0.28) or maximal blood flow ratio (0.41) ($p<0.05$) (Figure 1). The maximal blood flow ratio method failed to reduce variability in baseline blood flow.

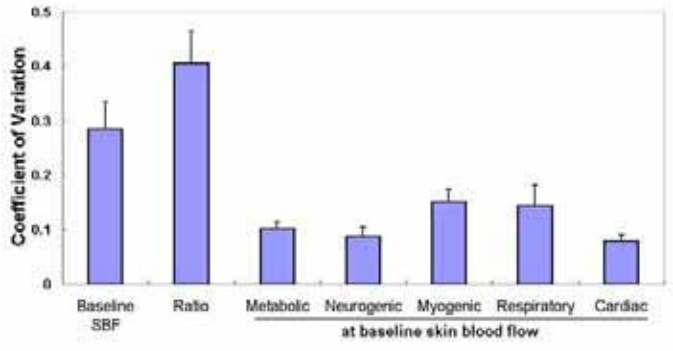

Figure 1. Comparisons of coefficients of variation of skin blood flow at baseline, maximal blood flow ratio method, and five characteristic frequency bands isolated from baseline blood flow in three consecutive weeks (values are mean±S.E.).

CONCLUSIONS

Our study suggests that wavelet analysis is effective in reducing temporal blood flow variability. To best of our knowledge, this is the first study published using wavelet analysis to investigate temporal variability of laser Doppler blood flow measurements. However, time-frequency approaches have been used widely in the study of heart rate variability. We postulated that the study of skin blood flow variability has great potential to advance understanding of blood flow control mechanisms and to provide early detection of pathological changes in the skin (i.e. foot ulcers in diabetes mellitus, survival of free flap and stage I pressure ulcer).

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