Autonomic Neuroscience: Basic and Clinical 178 (2013) 15–23

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

Enhanced spectral analysis of blood flow during post-occlusive reactive hyperaemia test in different tissue depths

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ARTICLE INFO

Article history:
Received 1 November 2012
Received in revised form 25 February 2013
Accepted 2 April 2013

Keywords:
Blood flow
Laser doppler flowmetry
Spectral analysis
Segmented spectral analysis
Schizophrenia

ABSTRACT

The objective of this study was to investigate the impairment of microcirculation in schizophrenic patients by means of spectral analysis of blood flow signals and to determine if microcirculation is unequally altered in different tissue depths. Furthermore, the impact of gender and age on the spectral parameters of the Laser Doppler Flowmetry (LDF) signal in healthy and diseased microcirculation are to be analysed. The segmented spectral analysis (SSA) algorithm was applied to LDF signals of a provoked post-ischemic stage and compared to the traditional total spectral analysis, hypothesizing that SSA reveals more detailed information on the dynamic behaviour of the blood flow. 15 healthy subjects (CON, mean age 32.4 years) and 15 patients (PAT, mean age 33.0 years) were enrolled. Spectral analysis was performed on two LDF signals at a depth of 2 mm and 6–8 mm. Features in five frequency subintervals were determined. Our results indicate that microcirculation is strongly impaired in patients. SSA of blood flow revealed differences between CON and PAT in all three frequency intervals referring to local vasomotion (endothelial $p = 0.03$; sympathetic $p = 0.02$, myogenic $p = 0.03$) as well as the respiratory ($p = 0.02$) and cardiac ($p = 0.006$) bands in the deeper tissue. In contrast, in the near-surface tissue only the endothelial ($p = 0.006$) and cardiac ($p = 0.006$) components were altered. Furthermore, SSA determined a gender- and age dependency regarding blood flow. In conclusion, we could demonstrate that microcirculation in schizophrenic patients is significantly impaired, depending on its location in the near-surface skin or in the superficial muscle tissue. These alterations of microcirculation are more pronounced in the deeper tissue depth of about 6–8 mm and are influenced by gender and age.

1. Introduction

Recently the analysis of peripheral circulation has revealed interesting results in the study of vascular pathological conditions (Rossi et al., 2006b). Different authors have suggested that the state of microcirculation of the skin is at least partly representative for the constitution of other vascular beds including the cardiac muscle and renal arteries (Izjerman et al., 2003; Stewart et al., 2004; Abularrage et al., 2005). The Laser Doppler Flowmetry (LDF) is a technology that facilitates the study of cutaneous microcirculation with the advantage of allowing continuous, non-invasive and real-time assessment of the skin perfusion in nearly all parts of the body (Nilsson et al., 1980).

Five relevant frequency subintervals were introduced for spectral analysis of blood flow signals in former studies (Bracic and Stefanovska, 1998; Stefanovska et al., 1999). Three of these intervals are associated with the local mechanisms of vasomotion, namely: the band from 0.01–0.02 Hz (vascular endothelial activity), the band from 0.02–0.06 Hz (neurogenic activity) and the band from 0.06–0.2 Hz (myogenic response). The other two bands are related to the transmission of global hemodynamic alterations to microcirculation: from 0.2–0.6 Hz (respiratory activity) as well as from 0.6–1.6 Hz (cardiac activity). For example, spectral skin blood flow parameters derived from an LDF signal were significantly altered in patients with stage II of peripheral arterial obstructive disease and critical limb ischemia in the diseased leg (Rossi and Carpi, 2004). Rossi et al. found a modified microcirculatory pattern in patients with essential arterial hypertension, depending on the duration of this hypertensive pathological condition (Rossi et al., 2006a).

Table 1
Patient data.

	CON	PAT
Number (male/female)	15 (7/8)	15 (7/8)
Mean age	33.0	32.4
Range	21–50	19–51

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http://dx.doi.org/10.1016/j.autneu.2013.04.002

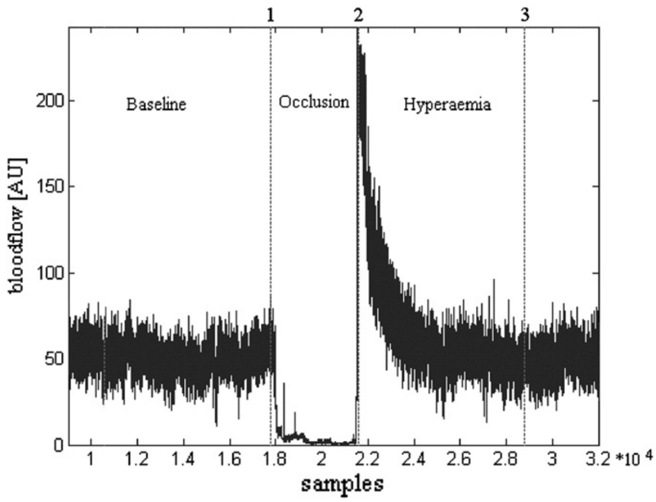

Fig. 1. An example of a LDF signal of PORH-test for a control subject. After a baseline measurement of approximately 10 min, a forearm ischemia was produced by a pneumatic cuff (occlusion). After 3 min, the cuff was deflated and registration of hyperaemia started.

Patients suffering from schizophrenia have an increased mortality risk due to cardiovascular events (Enger et al., 2004). It has been suggested that these events might be associated with cardiac autonomic dysregulation, specifically a decrease in vagal modulation and an increase in sympathetic activity. Bär et al. found a significant reduction of baroreflex sensitivity and heart rate variability as well as a considerable augmentation of QT variability and pupil dilation, indicating an autonomic imbalance (Bar et al., 2007a,b, 2008). Recently an enhanced spectral algorithm, the segmented spectral analysis (SSA), was introduced. This algorithm revealed significant modifications of spectral blood flow parameters in patients with acute schizophrenia when compared to a healthy control group (Seeck et al., 2011). Up until now there has been no detailed examination of the results related to the tissue depths of the registered LDF signal.

Table 2
Significances (Mann–Whitney-U-test) of frequency parameters between controls and patients for TSA and SSA (test 1); n.s. - not significant.

	D1		D2	
Subinterval	**TSA**	**SSA**	**TSA**	**SSA**
Endothelial	n.s.	0.006	n.s.	0.03
Neurogenic	n.s.	n.s.	n.s.	0.02
Myogenic	n.s.	n.s.	n.s.	0.03
Respiratory	n.s.	n.s.	n.s.	0.02
Cardiac	n.s.	0.006	0.001	0.006

The objective of this study was the analysis of spectral parameters of the LDF signal

- To compare the impairment of microcirculation in schizophrenic patients between the near-surface skin and in the superficial muscle tissue,
- To analyse the impact of gender and age on these results.

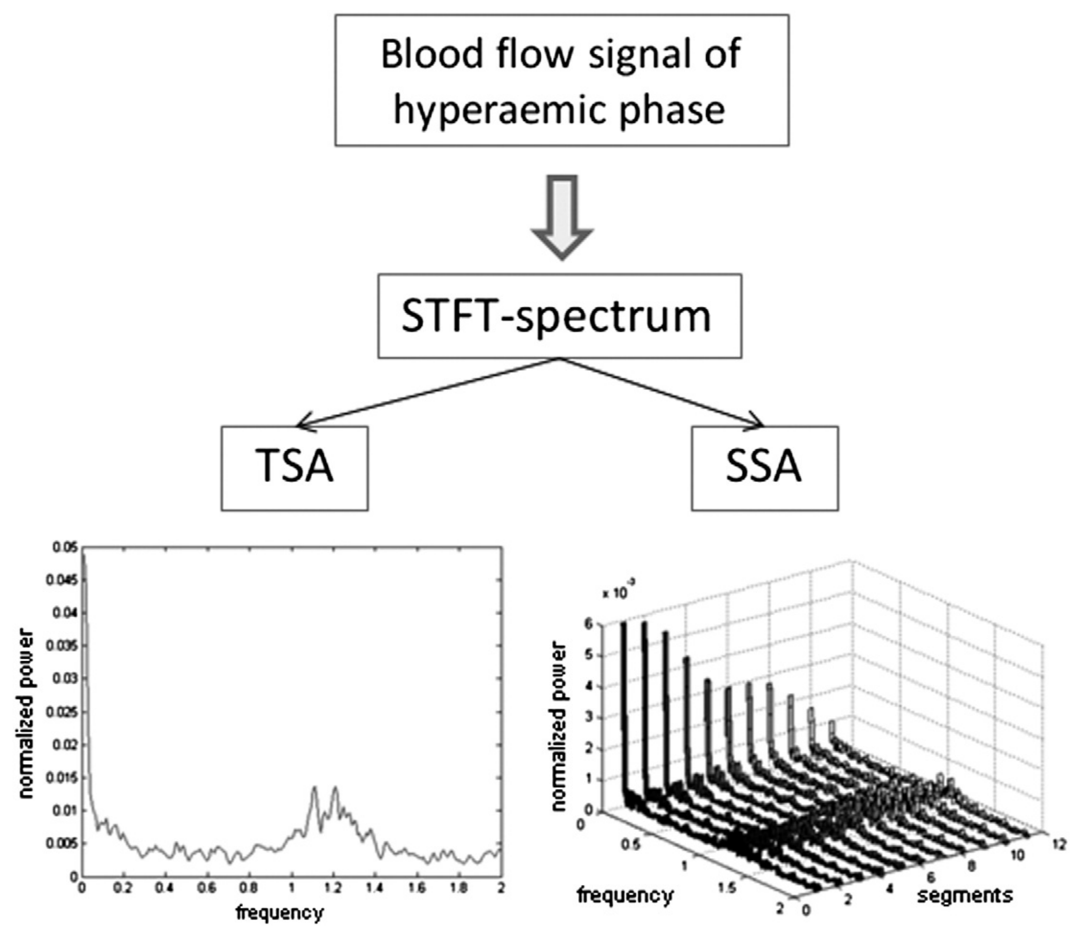

Fig. 2. Spectral analysis of blood flow signals; STFT - Short Time Fourier Transform, TSA - Total Spectral Analysis, SSA - Segmented Spectral Analysis. The STFT spectrum of a blood flow signal was reduced to a 2-D spectrum for TSA by summation of all spectral coefficients for all time steps related to one frequency. By comparison, the 3-D spectra are divided into temporal segments which were separately analyzed for SSA.