ANALYSIS OF CHANGES IN BLOOD FLOW OSCILLATIONS UNDER DIFFERENT PROBE PRESSURE USING LASER DOPPLER SPECTRUM DECOMPOSITION

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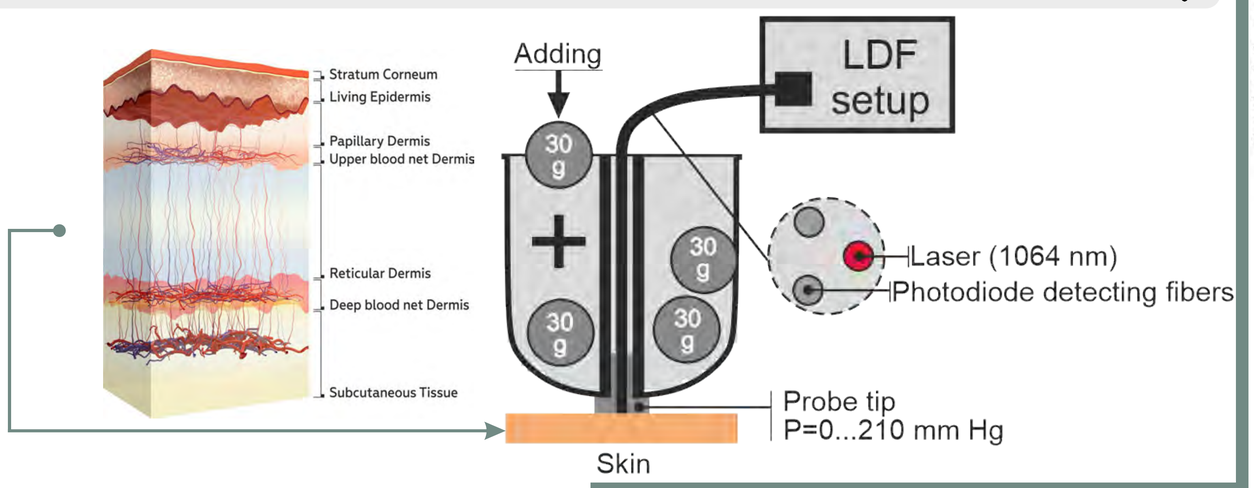
Introduction

- Blood perfusion is proportional the mean concentration and velocity of red blood cells in diagnostic volume.
- The averaging of the obtained Doppler-broadening spectrum according conventional laser Doppler flowmetry (cLDF) occurs with loss information about signal distribution.

Methodology

- Eight healthy volunteers;
- Special 3d-printed tooling and set of 30 g weights;
- Six stages of experiment: 0, 30, 90, 150, 210, 30 mm Hg;
- Duration of every stage: 10 minutes;
- LDF-setup consists: 1064-nm laser; two photodiodes; AC-DC amplification board; data acquisition board ;
- Full spectrum of Doppler shift is splited on 64 sub-ranges frequency sub-ranges and consequently integrated.
- Wavelet-analysis apparatus were involved in following signal

Setup



Signal processing

Processing of the one frequency band of Doppler shift:

$$PU(t) = \int_{f_i}^{f_j} f \cdot S(t,f)df$$

Perfusion computation on narrow frequency sub-range

$$W_x(t,\nu) = \sqrt{\nu} \cdot \int_{-\infty}^{\infty} PU(t)\psi^*(\nu(t-\tau))dt$$

Wavelet analysis with Morlet core function

$$M(\nu) = 1/T \int_0^T |W(\nu,t)|^2 dt$$

Global wavelet spectrum computation

$$E_{max} = max\left[M_j|_{0.01Hz}^{0.02Hz}\right]$$
$$N_{max} = max\left[M_j|_{0.02Hz}^{0.04Hz}\right]$$
$$M_{max} = max\left[M_j|_{0.04Hz}^{0.08Hz}\right]$$
$$B_{max} = max\left[M_j|_{0.08Hz}^{0.6Hz}\right]$$
$$C_{max} = max\left[M_j|_{0.6Hz}^{2Hz}\right]$$

Find maximums of wavelet oscillations of blood perfusion

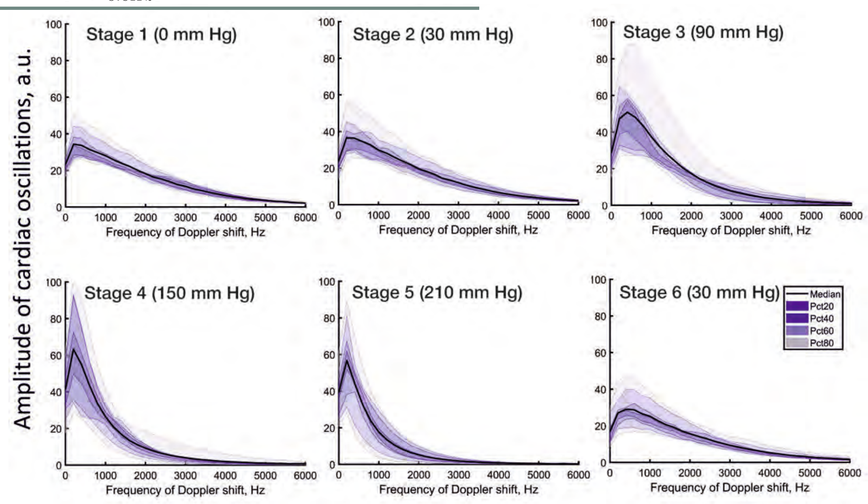


Figure 1 – Example of distribution of cardiac oscillations along frequency of Doppler shift

Analysis

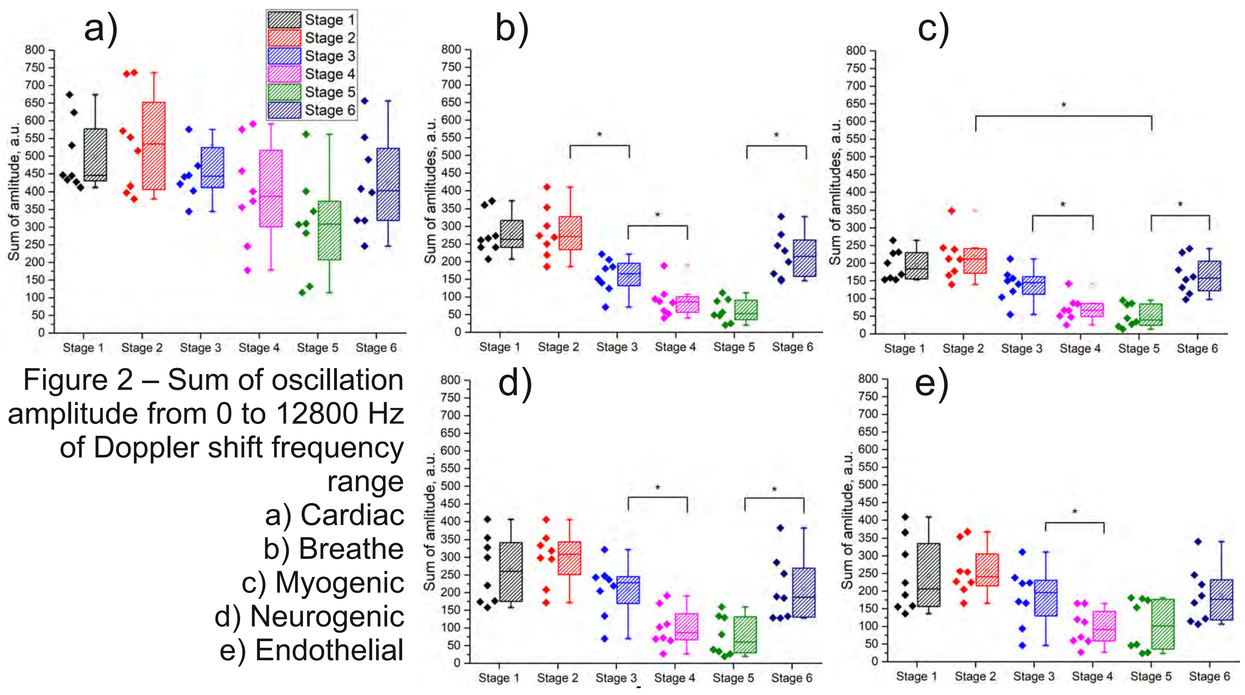


Figure 2 – Sum of oscillation amplitude from 0 to 12800 Hz of Doppler shift frequency range
a) Cardiac
b) Breathe
c) Myogenic
d) Neurogenic
e) Endothelial

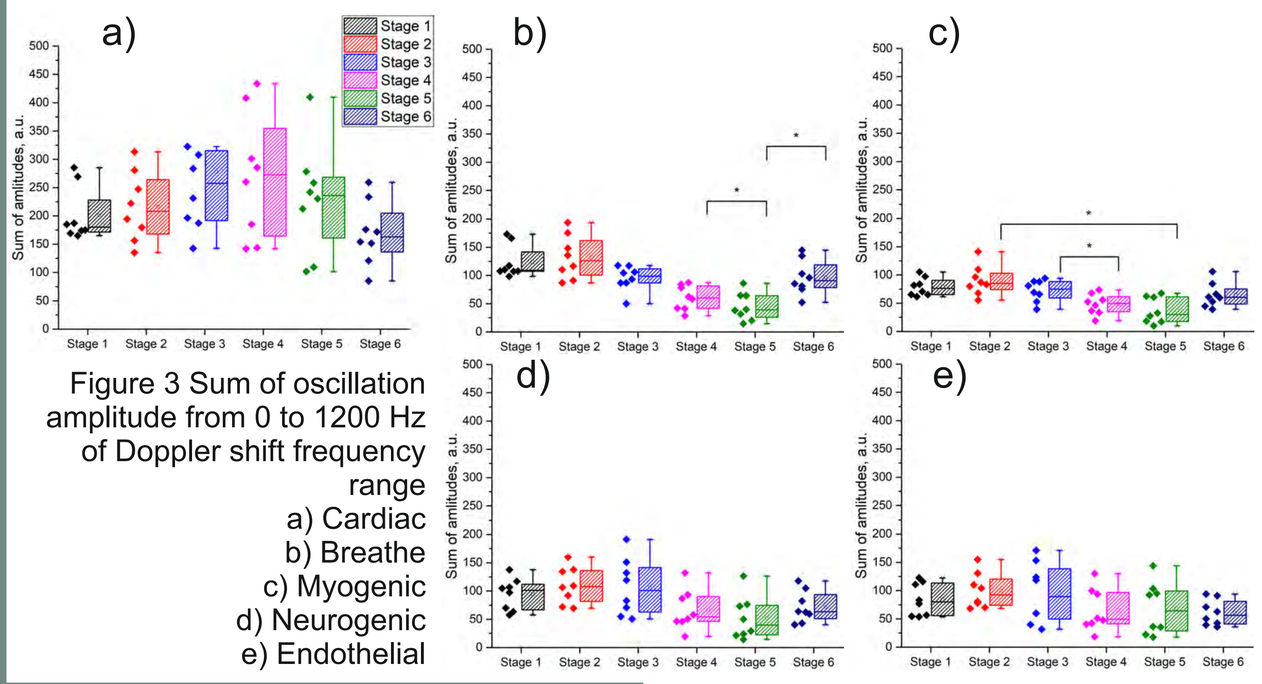


Figure 3 Sum of oscillation amplitude from 0 to 1200 Hz of Doppler shift frequency range
a) Cardiac
b) Breathe
c) Myogenic
d) Neurogenic
e) Endothelial

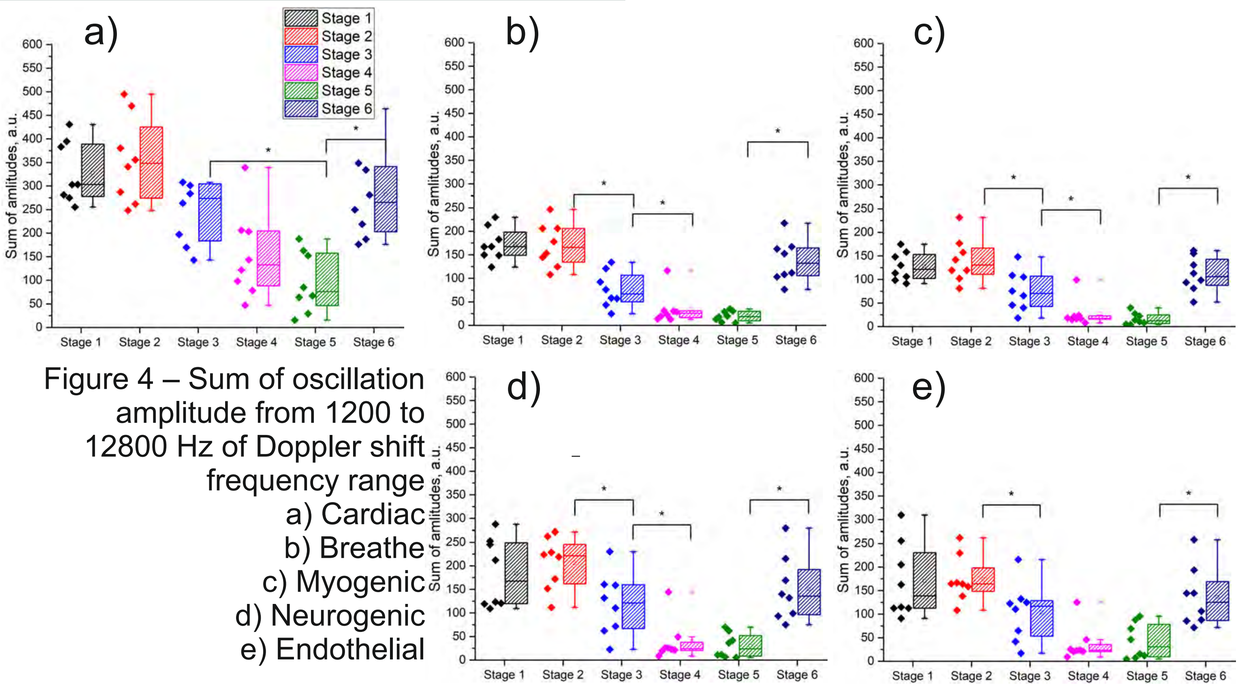


Figure 4 – Sum of oscillation amplitude from 1200 to 12800 Hz of Doppler shift frequency range
a) Cardiac
b) Breathe
c) Myogenic
d) Neurogenic
e) Endothelial

* Mann-Whitney test, $p<0.05$

Conclusion

- An increase in pressure does not lead to decrease in the sum of oscillation amplitudes of blood perfusion at the frequency ranges up to 1200 Hz;
- The sum of the cardiac oscillation amplitudes increases in the range up to 1200 Hz of Doppler shift frequencies;
- Pressure induced phenomena in blood flow can be explained in terms of redistribution of signal in different frequency ranges;
- Different integration ranges of Doppler shift frequencies have a different contribution in total blood perfusion oscillations.

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