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The Light Conditions Influence upon Blood Perfusion in the Duplex Mode

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Abstract: The study is focused on the experimental research of the ambient light influence upon the blood perfusion measurement in the clinical conditions. The measurement reliability of the perfusion maps was performed on the base of Doppler method with using PeriScan PIM 3 device. The analysis leads to the list of standards and recommendations serving for the reliability improvement and the compactness of the blood perfusion measuring in the clinical conditions. The light conditions influence upon blood perfusion brings the optimization of diagnostic process and therapy as well. The blood perfusion influence was analyzed in the duplex scanning mode. The blood perfusion was statistically evaluated in the dependence of natural, fluorescent and operating light. Statistical evaluation consist linear regression representing prediction model of the blood perfusion in the dependence of a respective source of light. The important part of statistical analysis is 95% confidence intervals characterizing the estimated range of blood perfusion.

Key words: Blood perfusion, light conditions, doppler method, statistical analysis, linear regression, part, list

INTRODUCTION

The blood perfusion measurement: The blood perfusion imaging by Laser Doppler Perfusion Imaging (LDPI) is a medical diagnostic imaging method which is based on the evaluation of the Doppler shift laser radiation which reflects itself from a moving blood elements typically erythrocytes by skin capillaries. This phenomenon creates the quantitative maps of the blood perfusion. This diagnostic method is frequently used in the burn medicine for the objective and non-invasive assessing of the burn trauma range and depth. By the clinical evaluation there is up to 35% errors, especially on the early stages after undergoing trauma. The correct adjusting of the thermic injuries depth is key fact for the optimization of the future diagnosis. The LDPI specificity and the sensitivity for the burn depth is determined approximately 95% (Stetinsky *et al*., 2015).

Scanning procedure: Although, the laser beam movement appears itself as continuous during the scanning each measurement is in the fact created from a set of discrete points.

The maximum number of measuring points can be 256×256, it means that in the one image is more than 65000 tissue points. Generally, it is appropriate to get average perfusion value along to many points because the perfusion value is suffered from noise and the spatial tissue variation in the every individual point. The spatial resolution is defined as the smallest object distance which is possible to recognize. The resolution is determined by the laser diameter (PeriScan PIM 3 allows 1 mm) and used scanning step. The highest scanning effectivity is reached in the case when the scanning step is equalled to the laser beam average. The smaller scanning step improves the visual representation of the scan but does not contribute any physiological relevant information.

Besides the perfusion scanning PeriScan PIM 3 allows the intensive scanning as well. This mode is constructed on the base the intensity of the laser beam back diffused to the photodetector regardless on the Doppler shift. The pixel dimensions of the intensive scan are equal as the perfusion scan. The intensive scan is useful for differentiation of the scanned object from background (Perimed, 2012; Klosova *et al*., 2013).

The PeriScan PIM 3 also contains the built-in compensation of the signal noise from lights supplied from the standard electrical site with the frequency 50/60 Hz (Fig. 1). The other ambient light fluctuations can also influence the measurement so that, it is appropriate to ensure the stable light conditions. The light conditions influence on imaging process is the subject of this analysis (Goei *et al*., 2016; Ida *et al*., 2015; Shin and Yi, 2016; Elamin *et al*., 2015; Kubicek *et al*., 2016).

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MATERIALS AND METHODS

LDPI Software: LDPI Software is the analytic tool especially intended for PeriScan systems. The software allows to user the exact numerical overviews of the measured parameters and the color perfusion maps as well. Physician is allowed to select and highlight the Region of Interest (RoI) for detailed the blood perfusion assessing in the highlighted spot (Fig. 2). The LDPI software allows the following scanning modes:

- Single mode
- Repeated mode
- Sequential mode
- Duplex mode

Fig. 1: The arm with the head of PeriScan PIM 3

The duplex mode allows the fluent measuring of the blood perfusion only in one discrete point. The measurement output is the curve of the blood perfusion dependence within the time. The sample frequency is adjusted on the 10 kHz and the sampling period is 10 m sec. In the ideal case the blood flowing plethysmography curve in the arteries is clearly observable. This phenomenon is caused by the change flowing in the arteries which is with the scattering centers concentration the blood perfusion expressing (Penhaker *et al*., 2011; Augustynek *et al*., 2011).

Measurement of the ambient light influence upon blood perfusion: The whole measurement experiment has been performed for the real clinical conditions of the burn centre university hospital in Ostrava. The main output of the experimental measurement of the blood perfusion is a set of recommendations for clinical staff to ensure the minimization of the ambient light influence, the standardization of workflow and the compactness of the achieved results.

The experimental measurement of the ambient light influence by the system PeriScan PIM 3 was going in two ambulances. The humidity and the temperature of workspace were measured by the system GFTH 95 Greisinger electronic. The atmospheric pressure was indicated by the wall barometer. The level of lighting was controlled by the lux meter VA8050 V and A instrument. The skin temperature of the investigated spot was tracked by touchless temperature meter, equally as the mercury sphygmomanometer for the blood pressure measurement and the heart rate. The following overview indicates conditions in the ambulance 1:

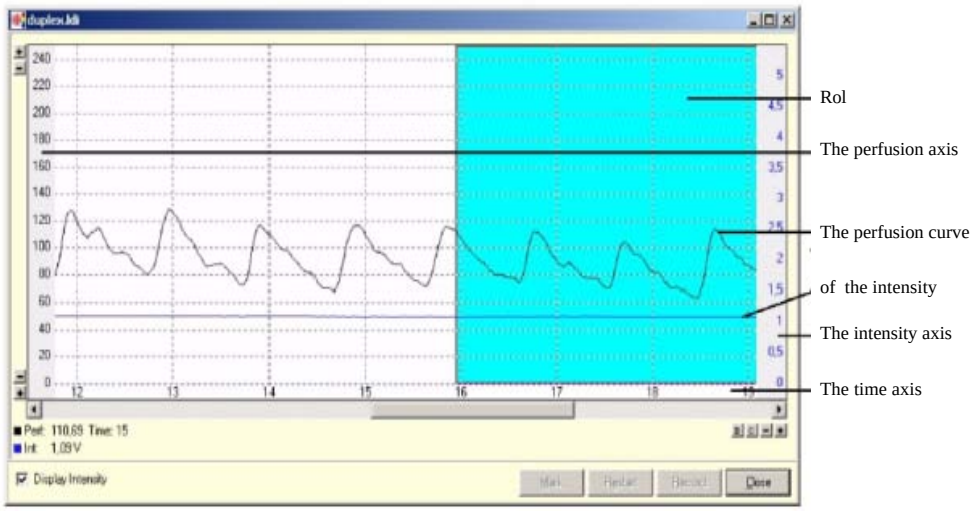

Fig. 2: The measurement output in the duplex mode. The graph shows the blood perfusion dependence within the time. The RoI is indicated by blue color. The quantified blood perfusion and other records are extracted from RoI

- The measurement time: 16:30-18:00
- The blood pressure: 150/95 mmHg
- The heart rate: 72 beats per min
- The spot temperature: 36.2°C
- The ambulance temperature: 24.1°C
- The relative ambulance humidity: 22.5%
- The atmospheric pressure: 101.2 kPa

It should be noted that, the tested person was woman who suffers from Raynaud's syndrome. This disease causes convulsive of a tiny blood vessels which leads to the blood supply failure of the human body peripheral parts, especially to the hand fingers.

The experiment layout: The spirit level was used to adjust of the scanning probe to the horizontal position to prevent a measurement error causing by incorrect position of the scanning probe. The measured spot was chosen the dorsal part side of the right forearm. The investigated spot should be as far flat as possible for avoiding of the measurement influence by angle change under which the laser beam falls on the skin. After adjusting of the tested person to correct position the light in the ambulance room was measured which is the main tracked parameter of this analysis. The light was measured only of the investigated skin spot within 10 points, directions in which the light falls on the spot. From the main source direction, it was the daylight, the fluorescent tube, operating light or halogen light. In the last step, the light was measured from the random environment. After counting the all ten numbers their arithmetical average was calculated. This parameter was used as a reference value of the particular measurement (Fig. 3).

RESULTS AND DISCUSSION

Statistical analysis of the experimental measurement: Besides the dependence of the blood perfusion on the ambient light, the dependence of the backscattered laser radiation intensity to the photo detector on the influence of ambient light was tracked as well.

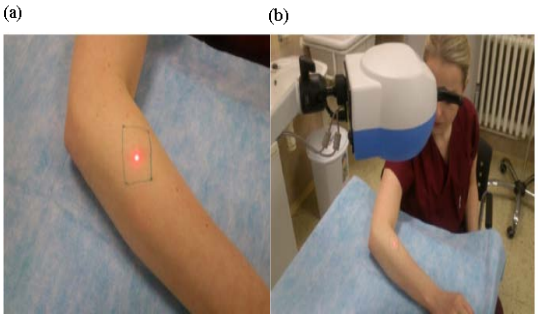

Fig. 3: a) The focusing spot of the tested person and b) The tested person in the ambulance

The linear regression was used for the reason of correlation assessing of the blood perfusion on the ambient light. This statistical method approximates a set of points by linear function and the consequent analysis of this linear function (Table 1).

The regression function slope a is negative and the respective confidential interval contains zero. The descending trend of regression function is statistically insignificant $p>0.05$. We can state that the measured value of the blood perfusion is statistically independent. Figure 4 shows graphical interpretation of the linear regression. The regression line is indicated by white color. The light gray field defines 95% confidence interval of individual values and darker gray field defines 95% interval of the average value. The measured values are indicated by black dots with circles. The regression slope a is positive and the confidence interval contains zero. The increasing trend of the regression line is statistically insignificant $p>0.05$. We can state that the measured value of the perfusion is statistically independent. Figure 5 shows graphical interpretation of the blood perfusion dependence on the fluorescent light (Table 2 and 3).

The regression slope a is negative and 95% confidence interval contains zero. The decreasing trend of the regression line is statistically insignificant. The $p<0.05$. We can state that the measured value of the blood perfusion is statistically independent. Figure 6 shows graphical interpretation of the blood perfusion linear regression on the operating light.

Standards proposal for blood perfusion measurement: The blood perfusion is not depended on the ambient light

Table 1: The statistical evaluation of the blood perfusion dependence on the natural light in the duplex mode

The duplex mode, perfusion, natural light					
		The regression function			
The pearson correlation		-------y = a-x+b-------		p-values	95% CI
The coefficient	p-value	b	154.57	0.0047	<79.081230.11>
-0.24	0.64	a	-0.22	0.6400	<-1.37, 0.95>

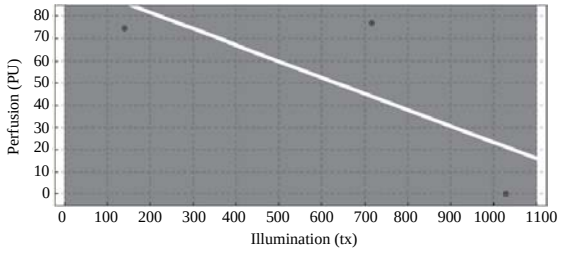

Fig. 4: The regression dependence of the blood perfusion on the natural light in the duplex mode

Table 2: The statistical evaluation of the blood perfusion dependence on the fluorescent light in the duplex mode

The duplex mode, perfusion, fluorescent light					
		The regression function			
The pearson correlation		-------y = a·x+b-------		p-values	95% CI
The coefficient	p-value	b	54.770	0.12	<-26.1, 135.6>
0.13	0.83	a	0.027	0.83	<-0.34, 0.41>

Table 3: The statistical evaluation of the blood perfusion dependence on the operating light in the duplex mode

The duplex mode, perfusion, operating light					
		The regression function			
The pearson correlation		-------y = a·x+b-------		p-values	95% CI
The coefficient	p-value	b	96.240	0.29	<-496.2, 688.7>
-0.751	0.46	a	-0.073	0.46	<-0.88, 0.74>

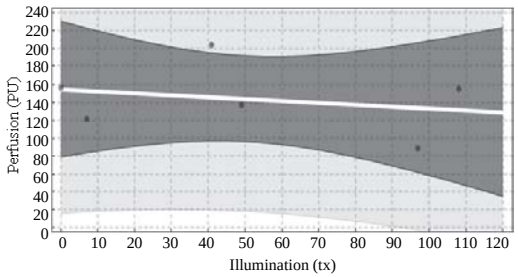

Fig. 5: The regression dependence of the blood perfusion on the fluorescent light in the duplex mode

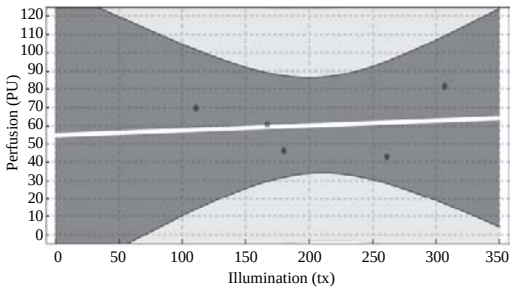

Fig. 6: The regression dependence of the blood perfusion on the operating light in the duplex mode

intensity in the duplex mode. The dependence was manifested itself neither within using the various kinds of lighting sources as natural and fluorescent light or operating light.

The reverse reflected beams intensity is not depended on the ambient light intensity in the duplex mode. The small statistical dependence of the intensity on the natural and fluorescent light was manifested itself. The intensity dependence on the operating light was not manifested in the duplex mode. The following rules should be generally kept for the measuring of the blood perfusion by the LDPI method:

- Use one predetermined room without windows or even with the possibility of sufficient darkening
- Use the firmly installed light sources to examination room lighting
- Use as maximum possible light intensity to examination room lighting as it is allowed. It prevents using of various light intensities by different staff
- Use material to underlay of the human body examined part which well absorbs the red colour spectrum
- Remove the investigated part of human body of liquid or gel substances which may distort the results of the blood perfusion measurement, especially caused by the Brown move

Examine of the patient in the stable and reproducible position. If it is allowed by patient health, condition use recumbence. The horizontal position in which patient is kept by a certain time before measurement keeps his physiological functions (the blood microcirculations, the blood pressure and the heart rate).

CONCLUSION

Within the analysis the series of the blood perfusion experimental measurements have been performed. The acquired data has been objectively evaluated. In the context our analysis the ambient light influence upon the blood perfusion in the clinical conditions is evaluated. The main applicable result of the analysis is set of standards and recommendations. The highest predictive value of the proposed standards is in the case of using PeriScan PIM 3.

Currently, set of standards and recommendations is being tested in the conditions of the clinical practice. The testing must be adjusted to the habitual workflow on the Burns department. We should objectively state that the analysis results are not completely unambiguous. The problem is the ensuring control on other conditions which may influence the blood perfusion measurement. The next problem is insufficient lighting adjustability and physiological instability of the tested persons. These facts also led to the lower number of the measurements. In the context of the mentioned facts we can consider this analysis as a pilot study which can serve for future research in the area of the blood perfusion measurement.

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