The Evaluation of Light Conditions Influence and Corrections upon Doppler Blood Perfusion Imagining

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Abstract. *The paper deals with theoretical and experimental research of the ambient light influence upon the measuring reliability of the perfusion maps by the laser Doppler method using the device PeriScan PIM 3. The main applicable result of the analysis is a set of recommendations for the standardization, the improving of reliability and the compactness of the blood perfusion measuring in the clinical practise. The improvement of examination brings more accurate results and contributes to the optimization of diagnostic process and therapy.*

Keywords

Ambient light, burns, Doppler effect, human skin, laser, laser Doppler measurement, LDI, LDPI.

1. Introduction

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 objective and non-invasive assessing of the burn trauma range and depth. By the clinical evaluation, there is up to 35 % errors especially in the early stages after undergoing trauma. The correct adjusting of the thermic injuries depth is a key fact for the optimization of the future diagnosis. The Laser Doppler Imaging (LDI) specificity and the sensitivity of the burn depth are determined approximately 95 % [1] and [2].

2. The Methodology

The studies of the ambient light were undertaken with the device PeriScan PIM 3, which uses a laser beam, generated by low intensity fixedly cloth laser with maximum power 1 mW, wavelength from 650 nm to 690 nm, and beam diameter 1 mm which sequentially scans the skin surface. The signal acquired by photodetector is consequently processed to obtain information about the microvascular blood flow. The superposition of the reflected beams invokes the current modulation in the photodetector. The Higher Doppler shift created by the quickly moving blood elements causes higher frequencies of the detector current, while the amplitude of the fluctuating current part is depended on the number of the moving blood elements. The perfusion is depended to the number and the speed of the moving blood elements.

The processor bandwidth, which is intended for the processing of the modulated current of photodetector, is $\Delta f_{\max} = 50$ Hz up to 15 kHz. The maximum of the detected velocity can be calculated from Doppler shift equation:

$$|v_{\max}| = \frac{1}{2}\lambda_0 \Delta f_{\max}, \tag{1}$$

where f denotes the frequency and λ_0 denotes the wavelength of used laser light. For The PeriScan PIM 3 it is [1], [2], [3], [4] and [9]:

$$|v_{\max}| \approx 5\,\mathrm{mm{\cdot}s^{-1}}. \qquad (2)$$

2.1. The Scanning

Although, the laser beam movement appears itself as continuous during the scanning, each measurement is in fact created from a set of discrete points. The maximal number of measuring points is 256 × 256, which means that in one image is more than 65 000 tissue points. Generally, it is appropriate to get average perfusion value along many points because the perfusion value is surrounded by noise and the spatial tissue variation in every individual point. The spatial resolution is defined as the minimum distance between distinguishable objects in an image. The resolution is determined by the laser diameter (PeriScan PIM 3 allows 1 mm) and used scanning step. The highest scanning effectivity is reached when the scanning step is equal to the laser beam average. Smaller scanning step improves the visual representation of the scan but does not contribute any physiologically relevant information.

PeriScan PIM 3 is the most frequently used device on Burn centres (Ostrava, Brno, and Prague) in the Czech Republic. This device allows a prediction, depth and evolution of the burn healing process. Currently, it is the most modern device from the view of price/performance.

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

PeriScan PIM 3 contains the software compensation of a signal noise caused by ambient light sources supplied from same electricity network 50 Hz (60 Hz for USA). Typical example from the clinical practice is a table-lamp in an examination room. The manufacturer states that the examination can be also influenced by other light fluctuations. It is recommended to ensure appropriate and stable light conditions in an examination room [5], [6], [7], [8], [10] and [11].

3. The Experimental Measurement of the Ambient Light Influence on the Blood Perfusion

The experimental measurement of ambient light influence on the blood perfusion was realized in the 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 ambient light influence, the standardization of workflow and the compactness of the achieved results.

3.1. The Controlled Experiment Conditions

The experimental measurement of the ambient light influence by the system PeriScan PIM 3 was carried out in two ambulances. The humidity and the temperature of workspace were measured by the system GFTH 95 Greisinger electronic (resolution: temperature 0.1 °C/humidity 0.1 RH, with relative temperature accuracy 3 %). The atmospheric pressure was indicated by the wall barometer. The level of lighting was controlled by the lux meter VA8050 V&A instrument. The skin temperature of the investigated spot was measured by non-contact thermometer, and mercury sphygmomanometer was used for the blood pressure and the heart rate measurement. The following overview indicates conditions in the ambulance 1:

- the measurement time: 16:30 to 18:00,
- the blood pressure: 150/95 mmHg,
- the heart rate: 72 beats per minute,
- 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 a woman who suffers from Raynaud's syndrome. This disease causes convulsion of a tiny blood vessels which leads to the blood supply failure of the human body peripheral parts, especially to the hand fingers.

3.2. The Experiment Progress

The spirit level was used to adjust the scanning probe to the horizontal position to prevent a measurement error caused by incorrect position of the scanning probe.

As a measured spot, the dorsal part of the right forearm was chosen. The investigated spot should be as far flat as possible to avoid the influence of an angle change under which the laser beam falls on the skin. After adjusting of the tested person to a correct position, the light in the ambulance room, which is the main tracked parameter of this analysis, was measured. The light was measured only on 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 all ten numbers, their arithmetic average was calculated. This parameter was used as a reference value of the particular measurement. The Fig. 1 shows examination on the PeriScan PIM 3.

Fig. 1: The focusing spot of the tested person (left), the tested person in the ambulance (right).

4. The Results of the Experimental Measurement and their Statistical Analysis

Besides the dependence of the blood perfusion on the ambient light, the dependence of the laser radiation intensity, which was backscattered to the photodetector, on the influence of ambient light was tracked as well. If the value of intensity threshold was incorrectly set, data bellow this value either would not be recorded, or would be distorted. Therefore, a correction of a set threshold value is important.

The linear regression was used for assessing the correlation between the blood perfusion and the ambient light. This statistical method approximates a set of points by a linear function and the consequent analysis of this linear function. Optimally, we need to achieve a narrow interval for the perfusion and intensity in the dependence of ambient light. Therefore, 95 % confidence interval with significance level ($\alpha = 5$ %) is used.

The regression line direction ($a = 0.0120$) is positive and the 95 % confidence interval contains a zero value (Tab. 1). The increasing trend of the regressive function is statistically insignificant. This statement can be proved by p-value ($p = 0.92$) which is greater than 0.05. We can state that the measured perfusion value is statistically independent.For assessing whether the perfusion is depended on the light, the null and the alternative hypothesis are set up:

Tab. 1: The dependence of the perfusion on the nature light.

Ambulance 1, single mode, perfusion, natural light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	75.229	$5.2 \cdot 10^{-4}$	<54.677, 95.781>
0.0525	0.92	a	0.0120	0.92	<−0.305, 0.329>

- H_0 - The perfusion is independent on the light.
- H_A - The perfusion is depended on the light.

On the base of the 5 % significance level, the null hypothesis was not rejected. The blood perfusion is not depended on the natural light influence.

The regression can be also expressed graphically (Fig. 2). The regression line is indicated by white colour. The light grey field takes the 95 % confidential interval of individual values and dark grey field takes the 95 % confidential interval of the average value.

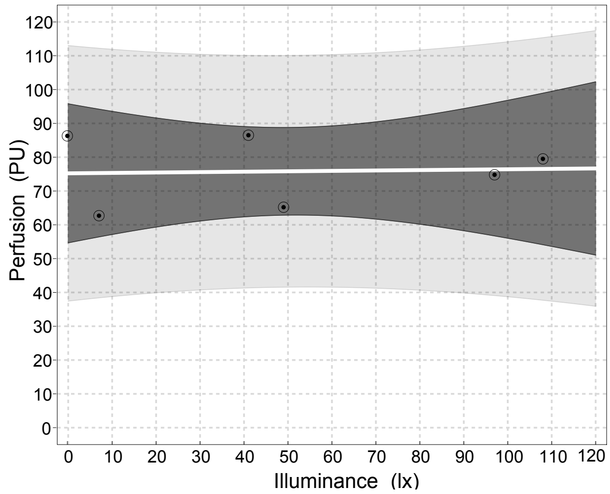

Fig. 2: The regression dependence of the perfusion on the natural light.

In this particular case, the regression line shows the descending tendency ($a = -0.021$) so that it is statistically insignificant. The p-value ($p = 0.57$) proves this fact which is greater than 0.05 (Tab. 2). We can state that the measured value of the perfusion is statistically independent. It is important to obtain information whether the perfusion is depended on the fluorescent light. For this reason we set up these hypotheses:

Tab. 2: The dependence of the perfusion on the fluorescent light.

Ambulance 1, single mode, perfusion, fluorescent light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	48.24	0.0072	<24.78, 71.71>
−0.34	0.57	a	−0.021	0.57	<−0.12, 0.086>

- H_0 - The perfusion is independent on the fluorescent light.
- H_A - The perfusion is depended on the fluorescent light.

On the base of the 5 % significance level, the null hypothesis was not rejected. The blood perfusion is not depended on the fluorescent light influence.

The following figure depicted the regression of the perfusion dependence on the fluorescent light (Fig. 3).

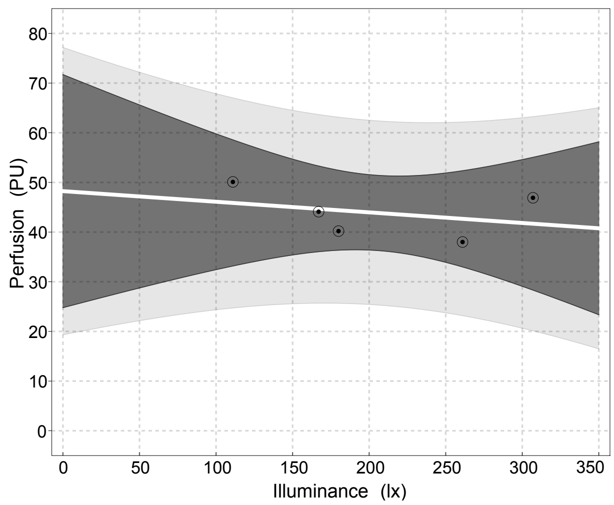

Fig. 3: Regression of the perfusion dependence on the fluorescent light.

Tab. 3: The dependence of the perfusion on the operating light.

Ambulance 1, single mode, perfusion, operating light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	58.14	0.37	<−430.76, 547>
−0.59	0.59	a	−0.039	0.59	<−0.71, 0.63>

Also in this case, the trend of the regression function is statistically insignificant. The regression line direction ($a = -0.039$) is negative. This statement can be proved on the base of the p-value ($p = 0.59$) which is greater than 0.05 (Tab. 3). We can state that the measured value of the perfusion is statistically independent. Statistical significance of the perfusion dependency on the operating light is estimated by the following statistical test:

- H_0 - The perfusion is independent on the operating light.
- H_A - The perfusion is depended on the operating light.

On the base of 5 % significance level, the null hypothesis was not rejected. The blood perfusion is not depended on the operating light influence.

The following figure shows the regression function (Fig. 4). The measured values are indicated by the black marker points.

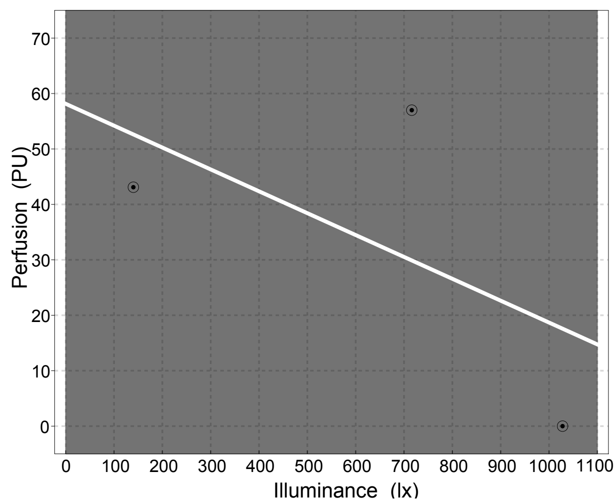

Fig. 4: The regression of the perfusion dependence on the operating light.

Tab. 4: The dependence of the intensity on the natural light.

Ambulance 1, single mode, intensity, natural light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	1.21	$1.1 \cdot 10^{-7}$	<1.17, 1.25>
0.077	0.88	a	$3 \cdot 10^{-4}$	0.88	<$-5.5 \cdot 10^{-4}$, $6.2 \cdot 10^{-4}$>

The regression direction is positive ($a = 3 \cdot 10^{-4}$), and the 95 % confidence interval contains zero. The increasing trend of the regression line is statistically insignificant. This statement is also proved by the p-value ($p = 0.88$) which is greater than 0.05 (Tab. 4). We can state that the measured value of the intensity is not statistically depended. The statistical dependence is confirmed by the following test:

- H_0 - The intensity is independent on the natural light.
- H_A - The intensity is depended on the natural light.

On the base of the 5 % significance level, the null hypothesis was not rejected. The intensity is not depended on the natural light influence.

The following figure shows the regression function (Fig. 5). The measured values are indicated by black marker points.

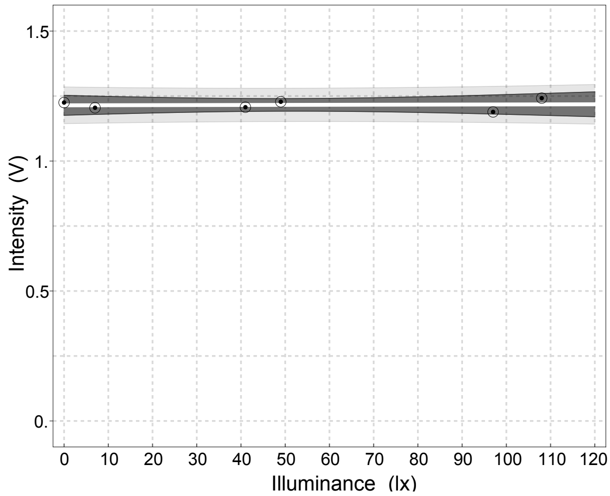

Fig. 5: Regression of the intensity dependence on the natural light.

Tab. 5: The dependence of the intensity on the fluorescent light.

Ambulance 1, single mode, intensity, fluorescent light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	58.14	0.37	<−430.76, 547>
−0.59	0.59	a	−0.039	0.59	<−0.71, 0.63>

The regression function exhibits itself the descending trend ($a = -0.039$), and it is statistically insignificant. The statement of the decrease can be also proved by the p-value ($p = 0.59$) which is greater than 0.05 (Tab. 5). We can state that the measured value of the intensity is statistically independent.

The following statistical test indicates whether the intensity is depended on the fluorescent light.

- H_0 - The intensity is independent on the fluorescent light.
- H_A - The intensity is depended on the fluorescent light.

On the base of the 5 % significance level, the null hypothesis was not rejected. The intensity is not depended on the fluorescent light influence.

The following figure shows the regression function (Fig. 6). The measured values are indicated via black points.

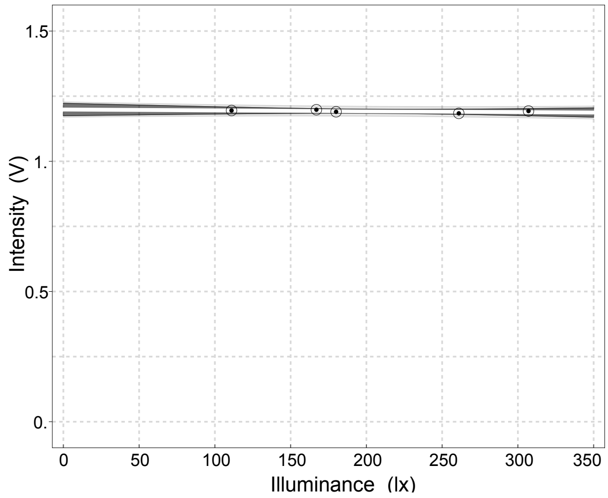

Fig. 6: Regression of the intensity dependence on the fluorescent light.

Tab. 6: The dependence of the intensity on the operating light.

Ambulance 1, single mode, intensity, operating light					
Pearson correlation		Regression function $y = a \cdot x + b$		p-value	95 % confidence interval
Coef.	p-value	b	1.51	0.26	<−6.91, 9.91>
−0.78	0.42	a	−0.012	0.42	<−0.012, 0.011>

The regression direction is negative ($a = -0.012$), and its 95 % confidence interval contains zero. The decreasing trend of the regression function is statistically insignificant. This statement is also proved by p-value ($p = 0.42$), which is greater than 0.05 (Tab. 6). We can state that the measured value of the intensity is not statistically significant. The following statistical test indicates whether the intensity is depended on the operating light.

- H_0 - The intensity is independent on the operating light.
- H_A - The intensity is depended on the operating light.

On the base of the 5 % significance level, the null hypothesis was not rejected. The intensity is not depended on the operating light influence.

The following figure shows the regression function (Fig. 7). The measured values are indicated via black points.

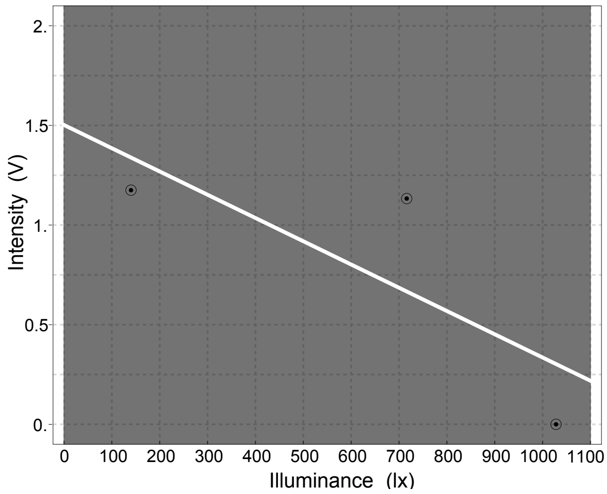

Fig. 7: The regression of the intensity dependence on the operating light.

5. The Methodology Proposal for Blood Perfusion Measurement

In the single mode, the blood perfusion is not depended on the ambient light intensity. The dependence was exhibited neither during the various types of light sources as natural light and fluorescent light or operating light.

The intensity of the backscattered beams is not depended on the ambient light intensity. The dependence was exhibited itself neither during the various kinds of the light sources as natural and fluorescent light.

The device PeriScan PIM 3 is used for the measuring of the blood perfusion on the various Burn centres. For this reason, we have designed the general standard guidelines for this examination regardless on the local conditions of an individual Burn centres. The dependence of the blood perfusion on the ambient light was not clearly proved but clinical conditions should be standardized. Especially the objectifications of the individual examinations should not be performed by same staff in same examination rooms.

5.1. The General Standard

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 maximal light intensity allowed in an examination room. It prevents using of various light intensities by different staff.
- Use a material to underlay the examined part of the human body which absorbs the red colour spectrum well.
- Remove liquid or gel substances from the investigated part of human body. It might distort the results of the blood perfusion measurement which is especially caused by the Brownian motion.
- Examine the patient in the stable and reproducible position. If it is allowed by patient health condition, use a recumbent position. The horizontal position, in which patient is kept for a certain time before measurement, keeps his physiological functions (the blood microcirculations, the blood pressure and the heart rate).

6. Conclusion

The main impact of the analysis is assessing of the blood perfusion imaging in the context of the disturbing influence of the ambient light. The set of the experimental measurement was performed and the acquired data were objectively evaluated. The analysis is especially focused on the ambient light influence on the blood perfusion measurement in clinical practise on the University hospital in Ostrava. On the base of the experimental results, the set of the recommendations has been proposed. This standard may be reliably applicable for all clinical examination rooms, where the device PeriScan PIM 3 is being used.

In the cooperation with the Burn centre of university hospital in Ostrava, physicians were handed in the proposed standard for the blood perfusion measurement. Nowadays, the testing of the set recommendations and rules is being performed in the clinical workspace. The testing should be adapted to the habitual clinical conditions of the medical departments. The light conditions of the blood perfusion measuring in dark room have not been investigated yet. Therefore, the future research should be focused on this topic. On the other hand, we should state that the analysis results are not unambiguous. The problem is ensuring of the control on the other conditions, which influence the blood perfusion measurement. The problem was also the insufficient lighting adjustability and the physiological instability of the tested person. In the context of the mentioned fact we can assess our analysis as a pilot study. Using the proposed standard for the blood perfusion measurement can become the new point of view and it can be the useful basis for the next studies in this area.

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