PERFUSION INDEX VALUES ARE CONSISTENT ACROSS COMMON LYING SURGICAL POSITIONS

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Abstract

Perfusion Index (PI) is an important vital sign in medical practice, with increasing utility in a variety of medical specialties. Its relevance extends to critical care and serves as a valuable measure of anesthetic efficacy. Despite its growing importance, there is a notable lack of literature on the potential impact of different surgical positions on PI measurements. Therefore, this study attempts to fill this gap by investigating whether PI exhibits variance in four different surgical positions: supine, prone, right and left lateral decubitus. The interventional prospective study included 27 volunteers who underwent PI measurement in each position in a randomized order. Using a one-way analysis of variance (ANOVA) for repeated measures, the results showed that at a 5% significance level, no significant differences were found in measured PI values between supine, prone, right and left lateral decubitus positions. Higher standard deviations in the right (±4.46%) and left (±4.58%) lateral decubitus positions indicate greater PI variability than in the supine (±3.91%) and prone (±3.88%) positions. The results suggest consistency of PI measurements across different surgical positions, adding to the knowledge of standardization of PI measurements and interpretation of measured absolute PI values.

Keywords

perfusion index, pulse oximeter, photoplethysmography signal, body positions

Introduction

Perfusion Index (PI) is a measure of tissue perfusion that allows, among other parameters, to assess the clinical condition of the patient. PI is calculated from a photoplethysmography (PPG) signal obtained using a pulse oximeter, and its values usually range from 0.02% to 20% [1]. PI is the ratio of the alternating part (pulsatile blood flow) to direct part of the blood flow (nonpulsatile blood flow + bone + tissues) [2].

PI is typically measured on the finger, as it provides a higher and more consistent PI value than other monitoring sites such as the ear [3]. Even when PI is measured on fingers, there is a difference between the measured PI values depending on which finger is used for measurement. A cross-sectional study showed that the highest PI value was found on the middle finger of both hands [4].

Although PI is a relatively new vital sign, it already has important applications in medicine. The study by Yamazaki et al. [5] showed that PI can be a good indicator of the effectiveness of anesthesia. In some patients, the stellate ganglion block (SGB) injection was effective in blocking the desired nerves, and in other patients, the SGB was not effective. After 5 minutes of SGB, PI increased by 61.4% in the earlobe and 60.5% in the upper limbs in patients in whom SGB was effective. In contrast, PI did not change significantly in patients in whom SGB was ineffective. In the case of intensive care units (ICU), the study by Er et al. [6] included sixty patients with risk factors for developing acute respiratory distress syndrome who were receiving mechanical ventilation support in the ICU. The study showed that critically ill patients had a decrease in PI levels 24 hours before death.

However, despite its established applications, there are still gaps in the standardization of PI measurements. PI is affected by several physiological factors, including temperature, as documented in the study by Hara et al. [7]. This variability hinders a clear and reliable interpretation of PI beyond observing trends over time, but there is still a lack of knowledge about how PI measurements might be affected by body position.

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The potential effect of body position on PI values may affect the interpretation of these measurements. In the prospective observational study by Tapar et al. [8], PI values of 61 healthy volunteers were compared in the supine, Trendelenburg, reverse Trendelenburg, 45-degree back-up sitting position, 45-degree legs-lifted supine and prone positions. There was a statistically significant difference in the PI values in the different positions as compared to the supine position.

In addition to the study by Tapar et al. [8], there was a study by Beurton et al. [9] that evaluated the effect of passive leg raising (PLR) on PI values in critically ill patients. Seventy-two patients were analyzed in this study. The study showed that in 34 patients, PI increased by 54% after PLR. In 38 patients, PI did not change significantly after PLR.

In clinical practice, patients may need to be moved into different positions, and it is crucial to understand how these positions affect PI values and therefore tissue perfusion. In particular, the lateral positions can lead to a shift blood flow distribution in the lungs, with the non-dependent lung showing increased distensibility [10]. This is further supported by the presence of a gravitational gradient of pulmonary perfusion in both supine and prone positions, with the distribution of lung parenchyma being more uniform in the prone position [11]. These findings underscore the need for further research to fully understand the impact of different body positions on PI values.

Although studies such as Tapar et al. [8] have evaluated PI in different patient positions, there is no consistent evidence as to whether lying positions specifically alter PI. Therefore, this study aims to evaluate the effect of 4 surgical body positions (supine, prone, right and left lateral decubitus) on PI.

Methods

The prospective interventional study was approved by the Institutional Review Board of the Faculty of Biomedical Engineering at the Czech Technical University in Prague (Act No. B10/2024).

Study group

Twenty-seven (16M + 11F) healthy volunteers (the group characteristics are shown in Table 1) participated in this study. Volunteers were selected based on inclusion criteria, which included being free of any known cardiovascular, respiratory or metabolic disease that could potentially affect peripheral perfusion. Exclusion criteria included a history of smoking, recent surgery, or acute illness within the previous month. Prior to participation, the potential risks and benefits of the study were explained to each volunteer and written informed consent was obtained.

Table 1: The basic characteristic of the group volunteers.

Parameter	Volunteers (N = 27)
Age (years)	22.3 ± 5.4 (19–48)
BMI (kg/m^2)	22.7 ± 3.7 (18.5–34.7)
LFC (mm)	50.3 ± 3.9 (43–60)
Systolic pressure (mmHg)	124.4 ± 11.4 (106–154)
Diastolic pressure (mmHg)	70 ± 11.9 (49–98)

The values are presented as mean ± standard deviation (minimum–maximum). Abbreviations: BMI—Body Mass Index; LFC—Left Finger Circumference.

Interventions

The experiment was conducted in a laboratory of the Faculty of Biomedical Engineering in Kladno. Upon arrival at the workplace, volunteers were instructed to relax in a comfortable seated position (relaxation period) for at least 10 minutes to stabilize physiological parameters.

The positions used in the study were supine, prone, right and left lateral decubitus. These positions were chosen because they are the most typical positions used during surgery and also provide good access to various anatomical sites, as described in the study by Armstrong et al. [12].

In the supine position volunteers were told to lay on the back with the head, neck and spine in a neutral position and the arms adducted alongside the body. In the prone position, volunteers lay on their front with the head, neck, and spine in a neutral position. In the right lateral decubitus position, volunteers were lying on their right side. In the left lateral decubitus position, volunteers were lying on their left side with their head resting on their left arm.

PI was assessed by a monitor of oxygenation Masimo Root (Masimo Corporation, Irwine, CA). PI was measured continuously on the middle finger of the left hand, at a sampling rate of 2 seconds. During the whole experiment, volunteers were told to remain as calm as possible to minimize motion artefacts.

Following the relaxation period, volunteers always started in the supine position and PI measurements were recorded for 5 minutes. Volunteers were then positioned in the other three positions and PI measurements were measured for 5 minutes in each position. The order of positions (prone, right and left lateral decubitus) was randomized for each volunteer to reduce potential bias associated with position order. The position order for 40 volunteers was randomized by assigning numerical values to each body position. Using the Fisher-Yates algorithm, balanced random sequences were generated to ensure that each position appeared equally. These sequences were then further randomized to eliminate any bias.

Between each position change, volunteers returned to the supine position for 3 minutes for a short rest period (resting period). The resting period was used to

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standardize the experimental conditions and to allow comparison of PI measurements between different body positions. During the resting period, PI was also measured continuously for 3 minutes to ensure consistency of data collection procedures. Fig. 1 shows the whole experimental procedure for one volunteer during the 26 minutes.

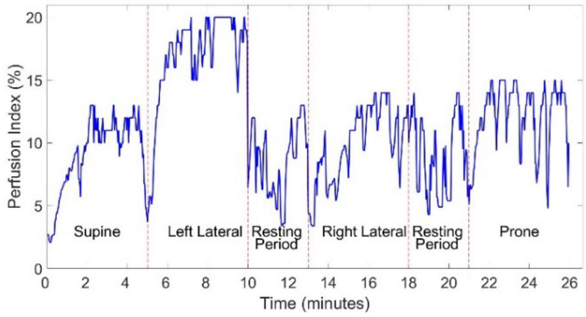

Fig. 1: PI course during the 26 minutes of the experiment for one volunteer.

Statistical Analysis

Based on the results of previous studies, PI stabilization after changing position typically takes about two minutes on average. Fig. 1 provides an illustrative example of this process for one volunteer. This stabilization period was excluded from the statistical analysis as it was not relevant to the comparison of PI across the four positions. The two resting periods were also excluded from the comparison. Therefore, 3 minutes from each position were used in the statistical analysis.

Based on our previous experience that the perfusion index is log-normally distributed in the population, the data were logarithmized. A Lilliefors test was then performed to test the normality of the data at each position, with a p-value of less than 0.05 considered statistically significant. The null hypothesis assumed a normal distribution of the measured data (p-value > 0.05). All p-values for all positions were greater than 0.05. The distribution of the logarithmized PI across all volunteers is shown in Fig. 2 using histograms for each position.

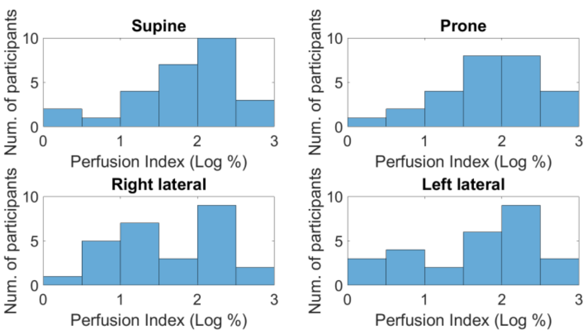

Fig. 2: Histograms of the logarithmized data for supine, prone, right and left lateral decubitus positions.

To test if there were differences on the PI between the positions, one-way ANOVA for repeated measures was performed. A p-value < 0.05 was considered statistically significant.

Results

The time course of the mean PI for all volunteers at each position over 3 min is shown in Fig. 3. There is no apparent change in PI over time for any of the body positions.

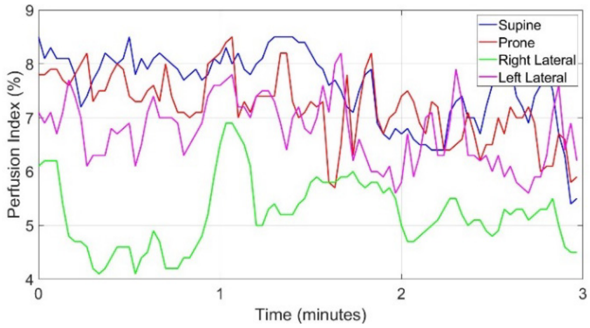

Fig. 3: Mean PI in the supine, prone, right and left lateral decubitus positions over the three minutes evaluated.

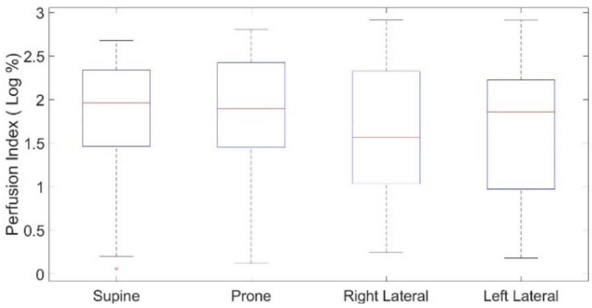

Fig. 4: Boxplots for the comparison of PI in supine, prone, right and left lateral decubitus.

The p-value of the ANOVA one-way for repeated measures was 0.62. Along with the test, the box plots in Fig. 4 show that the mean PI values of each position do not significantly differ from each other. The standard deviations for supine, prone, right and left lateral decubitus were ±3.91%, ±3.88%, ±4.46% and ±4.58% respectively.

Discussion

The main finding of this study is that there are no significant differences in the measured PI values on one finger between the common lying body positions at the 5% significance level. This is supported by the ANOVA test which yielded a p-value of 0.62,

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indicating no statistically significant difference in PI values between the supine, prone, right and left lateral decubitus positions. However, higher standard deviations in the right (±4.46%) and left (±4.58%) lateral decubitus positions indicate greater PI variability than in the supine (±3.91%) and prone (±3.88%) positions. Although the absolute differences in standard deviations are relatively small, they have some degree of variation between the positions. The increase in standard deviations in the lateral positions could be due to the uneven distribution of body weight and pressure on the measurement site.

The study by Tapar et al. [8], showed that there were significant differences in the PI values in the different positions compared to the supine position. However, the positions that were used in this study for the comparison were Trendelenburg, reverse Trendelenburg, 45-degree back-up sitting position, 45-degree legs-lifted supine and prone positions. The duration of measurements was 10 minutes in each position. The largest difference in PI in this study was between the Trendelenburg position and the 45-degree back-up sitting position, with the first one being 73.3% higher. Trendelenburg position can increase central blood volume, venous return to the heart, and mean arterial pressure, increasing PI values [13]. The only positions that can be compared with our study are the prone and supine positions.

In the study by Tapar et al. [8] the mean PI values for supine and prone positions were 7% and 6% respectively. The results of our study are in line with the above study with the mean PI values for supine and prone positions 7.8% and 7.2% respectively.

In the supine, prone, right and left lateral decubitus positions, the head, neck, spine and legs remain in a neutral position. In the Trendelenburg position, however, the legs are raised higher than the head, typically at an angle of about 15 to 30 degrees. So, this could be relevant in understanding why there are differences between positions in the study by Tapar et al. [8], but not in our study.

In the study by Beurton et al. [9], 34 out of 72 critically ill patients showed an increase in PI values after passive leg raising. However, this study cannot be compared to our study, since the body positions used were not the same, and our study included only young healthy volunteers.

The head resting on the arm during the left lateral decubitus position may affect blood flow, resulting in lower or more variable PI values. This could make both PI and its standard deviation time dependent. However, our study design, including randomized positions and a stabilization period, minimized such effects. The lack of significant differences in PI between positions suggests that any time-dependent variations were not sufficient to affect the results. Further studies could investigate this with longer measurement periods and additional controls.

The study has several limitations. Firstly, only healthy and young volunteers were included in the study. Next, randomization of the prone, right and left lateral decubitus was done for an expected 40 volunteers. Randomization was initially planned for 40 scheduled volunteers, but 13 were later excluded due to non-attendance. However, this limitation did not have an impact on the results, since no trend was found showing any bias associated with the position order. Also, the measurements were done on one hand only, and with a device of a single manufacturer. It would be advisable to repeat the measurements in both hands, using devices from other manufacturers, and for a longer period of time, for 10 minutes in each position, for example.

Conclusion

Although PI is a relatively new parameter, it has already found application in a number of medical specialties. This study documents that PI values do not differ significantly between the supine, prone, right and left lateral decubitus positions, which are the most common surgical lying positions. These findings extend the knowledge of standardizing PI measurements and interpreting the absolute PI values measured.

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