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Use of Perfusion Index to Monitor Quality of Cardiopulmonary Resuscitation

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Abstract

Background: Resuscitation science has gained significant advancements over the past 60 years. The American Heart Association recommends the use of physiological monitoring to give real time feedback, with the aim of improving the quality of resuscitation performed. Invasive blood pressure measurements and end tidal carbon dioxide levels are currently recommended as first line monitoring methods. However, these methods are either invasive, dependent on an advanced airway and may not always be available. There is a need for a readily available, non – invasive, easy to use device. The perfusion index may serve as such a measure.
Objective: To establish an association between perfusion index and return of spontaneous circulation during cardiac arrest.
Methods: A cross-sectional observation study was conducted in the intensive care unit of a tertiary level facility. Patients were recruited following a witnessed cardiac arrest, where resuscitation was commenced. A Masimo Signal Extraction pulse oximeter (SpO2, RX00004964) was attached to the patient at the start of resuscitation. The device measured and recorded perfusion index values against a timestamp. Individual patient data were exported as a comma separated variable file to R Core Team® version 4.2.1(2022) for analysis. Corresponding clinical data was collected for each participant.
Results: The median time-weighted average (IQR) in perfusion index was higher in those achieving return of spontaneous circulation ($0.82\ (0.43, 1.09)\%$) compared to those who did not ($0.18\ (0.09, 0.30)\%$), $p < 0.001$. Furthermore, a time-weighted mean perfusion index of $> 0.69\%$ was critical in prediction of return of spontaneous circulation.
Conclusion: Perfusion index values were higher in the group which achieved return of spontaneous circulation, compared to the group which failed. Perfusion index may have utility in monitoring the quality of cardiopulmonary resuscitation performed.

Keywords: *Cardiac Arrest; Cardiopulmonary; Perfusion-Index; Circulation; Resuscitation*

1. Introduction

Cardiac arrest is the complete cessation of spontaneous cardiac activity leading to lack of blood flow in the body. Closed cardiopulmonary resuscitation (CPR) involves the artificial reestablishment of blood flow to vital organs (heart and brain) following cardiac arrest (Lurie et al. 2016). Provision of adequate artificial perfusion is the main determinant of survival following cardiac arrest.

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In order to monitor and improve CPR quality, there is need for tools that provide real time feedback to responders (Lurie et al. 2016, Bobrow et al. 2013). The American Heart Association (AHA) recommends the use of invasive arterial pressure monitoring and end tidal carbon dioxide (ETCO2) as quality measures of CPR. Invasive pressure measurements are time-consuming and cumbersome in resuscitation situations, and are very rarely practical. ETCO2 measurements require presence of a capnometer with an advanced airway (Sutton et al. 2016).

Perfusion index (PI) may serve as an alternative monitor for CPR quality. It is obtained from pulse oximetry and is computed as the ratio of the pulsatile (alternating current) signal to the non-pulsatile (direct current) signal of infra-red light, expressed as a percentage (Broch et al. 2011).

$$PI = \frac{AC_{IR}}{DC_{IR}} * 100\% \quad (1)$$

Where:

- AC = pulsatile component of the signal
- DC = non-pulsatile component of the signal
- IR = infrared light

PI is a numerical measure of quality of blood flow and perfusion at the sensor site and reflects the global perfusion state of the body (Yigit et al. 2018). Its measurement is non-invasive, real-time, quick and requires no specialised training. The values of PI range from 0.02% in low perfusion states to 20.0% in increased perfusion states (Piasek, Van Bel, and Sola 2014). Lima and colleagues determined a median value of 1.4% in the normal population and noted values less than 1.4% in the critically ill indicated presence of poor peripheral perfusion (Lima, Beelen, and Bakker 2002).

Measurement of perfusion index is due to isolation of the pulsatile arterial signal as a result of pulse related variations in vessel caliber leading to changes in measured optical distance. Determination of the pulsatile signal uses the principle of the Lambert Law (Kocsis, Herman, and Eke 2006). It states that "equal parts in the same absorbing medium absorb equal fractions of the light that enters them."

Arterial blood flow yields a pulsatile absorption-over-time signal, while venous blood and tissues project a non-pulsatile signal. The distance that light travels through the arteries changes with each pulsation, as blood flows through them. The ratio of pulsatile to non-pulsatile absorbance is compared, to yield the perfusion index, and is used to assess tissue blood flow (Lima, Beelen, and Bakker 2002).

Cardiac arrest is denoted by the absence of pulsatile blood flow (Genbrugge et al. 2016). Plethysmographic waveform cannot be detected or perfusion index value recorded. Additionally, regulatory mechanisms are impaired and hence perfusion of peripheral tissue may only be affected by the quality of CPR performed (Abella et al. 2005).

The objective was therefore to establish the relationship between perfusion index and the return of spontaneous cardiac activity (ROSC).

2. Material & Methods

This was a cross-sectional observation study on patients who were being resuscitated following witnessed cardiac arrest in a tertiary hospital surgical intensive care unit. We hypothesized that survivors of cardiac arrest achieved higher perfusion index during CPR than non-survivors.

The main objective was to establish an association between perfusion index and return of spontaneous circulation (ROSC). Through consecutive sampling, 87 patients were enrolled into the study. Such patients were above 18 years of age, undergoing cardiopulmonary resuscitation for at least 3 minutes following witnessed cardiac arrest. Patients with peripheral vascular disease, valvular heart disease and at least 2 inotropes or vasopressors were excluded from the study. The study was registered by the KNH-UoN Ethics and Research Committee (KNH-UoN ERC), Ref: KNH-ERC/A/326.

Following cardiac arrest, a Masimo Signal Extraction (SET®) pulse oximeter (SpO2, RX00004964) was attached to the right middle finger. The right middle finger provides the most accurate perfusion index reading (from deep palmer arterial arch) of all the digits, both during states of normoperfusion and hypoperfusion (Mizukoshi et al. 2009).

The device reads and records pulse rate (PR), peripheral oxygen saturation (SPO2) and perfusion index against a timestamp. This data was collected on a second to second basis, and was retrieved for analysis once the resuscitative efforts were concluded. Individual patient data were exported as comma separated variable (csv) files to R Core Team® version 4.2.1(2022) for pre-processing and analysis.

Visualization of the perfusion index against time was done for every subject, with the time weighted mean perfusion index (TWPI) plotted as the red horizontal line shown in figure 1 below. This metric was obtained by computation of the area under curve (AUC) of the perfusion index-time graph divided by the duration of resuscitation.

$$AUC = \int_{time_{min}}^{time_{max}} PI \quad (2)$$

$$TWPI = \frac{AUC}{Duration\ of\ CPR} \quad (3)$$

Apart from the time-weighted mean PI, other variables such as age, gender, primary diagnosis, arrest rhythm, duration of CPR, use of vasoactives and achievement of ROSC were collected.

Normality for continous variables was established using the *Shapiro Wilk test*. All the numeric data were non-parametric and were sumarized in medians and inter-quartile ranges (IQR). For bi-variate analysis, the *Wilcoxon rank sum test* was used. Categorical variables on the other hand were summarized as frequencies and percentages. *Pearson's Chi-squared test* was used to test associations between categorical variables. A decision tree classification algorithm was used to estimate the critical time weighted mean perfusion index that was associated with ROSC.

3. Results

87 patients were enrolled into the study. Their median (IQR) age was 35(29, 53) years. Majority of them were male 70(80%), with polytrauma 29(33%) as the commonest admitting diagnosis. Pulse electrical activity (PEA) was the most frequent arrest rhythm (49%). The patients were resuscitated for a median (IQR) duration of 8.1(5.2, 11.8) minutes.

32.2% of the patients, (28 out of 87) achieved return of spontaneous cardiac function (ROSC). These patients were similar to those that failed to achieve ROSC in all aspects except the time-weighted mean perfusion-index. The median time-weighted average in perfusion index (IQR) was higher in those achieving ROSC (0.82 (0.43, 1.00)%) than in those who did not (0.18 (0.09, 0.30)%), $p < 0.001$. Additionally, a time-weighted mean PI of $> 0.69\%$ was considered critical in prediction of ROSC.

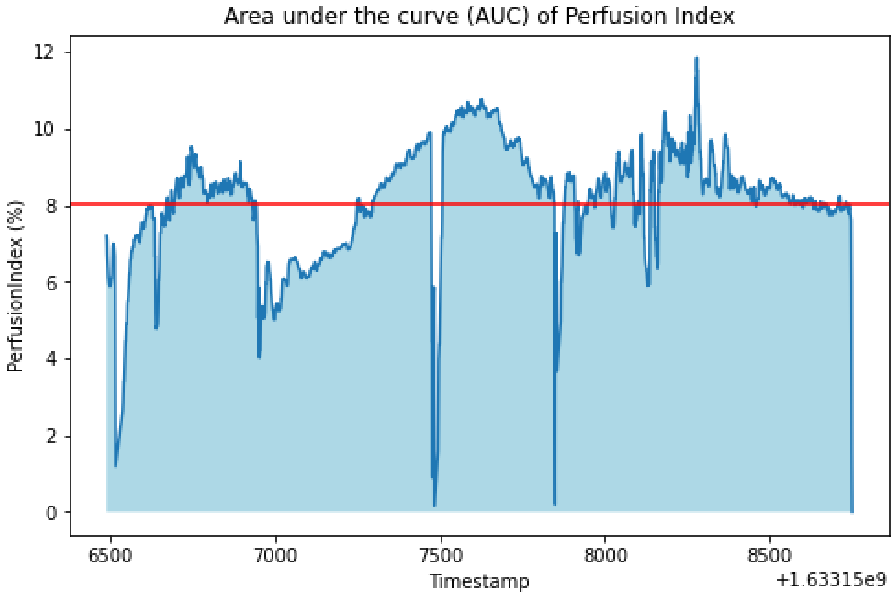

Figure 1. Time Weighted Mean PI of 8.0%

Table 1. Bivariate Statistics

ROSC	No,N=59	Yes,N=28	p-value[1]
Age (years)[2]	35(28,51)	37(29,59)	0.8
Gender, n(%)			0.14
Male	50(85%)	20(71%)	
Female	17(15%)	8(29%)	
Diagnosis, n(%)			0.2
Polytrauma	21(36%)	8(29%)	
Traumatic Brain Injury	18(31%)	8(29%)	
Sepsis	6(10%)	0(0%)	
Other	14(12%)	12(43%)	
Rhytms, n(%)			0.7
Pulseless Electrical Activity	27(46%)	16(57%)	
Asystole	20(34%)	6(21%)	
Ventricular Fibrillation	7(12%)	3(11%)	
Ventricular Tachycardia	5(8.5%)	3(11%)	
Duration of CPR[2]	8.5(5.2,12.9)	7.0(5.5,9.6)	0.5
Time Weighted Mean Perfusion Index[2]	0.18(0.09,0.30)	0.82(0.43,1.09)	<0.001***

Willcoxon rank sum test; Pearsons's Chi-square test; Fischer's exact test[1]
Median (IQR)[2]

4. Discussion

The median age of the study subjects was 35 years, with a nearly 4:1 male to female ratio. A South African study looking at critical care outcomes of traumatic brain injury revealed mean age 34 years, with an almost comparable male: female ratio of 3:1 (Tobi, Azeez, and Agbedia 2016). Trauma patients are significantly older in other parts of the world, with median age being > 46 years (Llompart-Pou et al. 2016, Chrysou et al. 2017).

Pulseless Electrical Activituy (49%) was the commonest arrest rhthym recorded in the study. In other local studies, non-shockable rhythms were similarly found to occur at higher frequencies than shockable ones (Wachira and Tyler 2015, Ngunga et al. 2017).

A multivariate analysis revealed that age, gender, cardiac arrest rhythm, comorbidities, primary diagnosis and CPR duration had no significant statistical association with the return of spontaneous circulation (ROSC). Additional variables such as number of chest compression cycles were similarly shown to have no influence on the achievement of ROSC (Kitua et al. 2016).

The median (IQR) time-weighted mean perfusion index was higher in participants who achieved ROSC $(0.82(0.43, 1.00))$ compared to those who failed to achieve ROSC $(0.18(0.09, 0.30))$, $p < 0.001$. Studies investigating the role of perfusion index during cardiac arrest in humans are currently lacking. However, the mean perfusion index after return of spontaneous circulation was noted to be higher in survivors $(1.9\% + / - 1.5\%)$ compared to non – survivors $(1.2\% + / - 0.9\%)$ of cardiac arrest. Additionally, patients who sustained mean perfusion index values of $\geq$2.5% for more than 30 minutes after cardiopulmonary resuscitation had a greater thirty-day survival (Savastano et al. 2017).

In this study, a time weighted mean perfusion index value greater than 0.69% was shown to predict the return of spontaneous circulation with a sensitivity of 73.9%, and a specificity of 84.5%.

5. Conclusion

Perfusion index values were significantly higher in the group that achieved return of spontaneous circulation compared to the group that did not. The time-weighted mean perfusion index may be used as a real-time feedback during cardiopulmonary resuscitation.

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