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Original Article

Correlation of pulse oximetry oxygen saturation with blood gas arterial oxygen saturation in patients with heart failure reduced ejection fraction: Prospective cohort study

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Abstract

Aim: An estimation of accurate oxygen saturation is a critical in the management of patients with heart failure (HF). However, obtaining peripheral arterial blood samples may be technically difficult in some cases. The purpose of this study was to evaluate the correlation of pulse oximetry SO_2 with arterial SO_2 in patients with HF reduced ejection fraction (HFrEF).

Material and Methods: In total, 29 consecutive patients who were admitted to cardiology clinics with HFrEF were prospectively enrolled in this study. We enrolled all patients if the chief physician ordered an atrial blood gas analysis. Simultaneous atrial blood gas sample and pulse oximetry measurements were collected and compared. The strength of association between atrial blood gas and pulse oximetry measurements was determined by Pearson correlation and Bland and Altman analysis.

Results: We evaluated 29 heart failure patients (the mean age was; 70.7±10.9, 44.8 % of patients were male) with a mean EF of 29.6 ± 5.5. We observed that the mean pulse oximetry SO_2 and arterial SO_2 in the study were 92.8 ± 4.4 and 93 ± 5.2, respectively. We found significantly positive linear correlation between two methods according to Pearson analysis ($r = 0.683$, $p < 0.001$). A low bias was found between two methods according to Bland and Altman method (-0.2296, $p = 0.23$).

Conclusion: The present data may suggest that pulse oximetry oxygen saturation is an acceptable substitute for the arterial oxygen saturation in patients with HFrEF.

Keywords: Arterial oxygen saturation; correlation; heart failure; pulse oximetry oxygen

INTRODUCTION

Arterial blood gas analysis is indisputably more accurate than pulse oximetry. However, it is more difficult to obtain, more painful and expensive in addition to lasting longer time to obtain result. Some clinical studies have investigated the accuracy of pulse oximetry SO_2 with arterial SO_2 in patients with uremic acidosis, diabetic ketoacidosis, acute pulmonary edema, and living in high altitudes (1-5) However, there are few studies which mainly focused on the accuracy of pulse oximetry saturation in patients with heart failure (HF). Although pulse oximetry oxygen measurement is frequently used in daily clinical practice, it is not known whether there is a correlation between pulse oximetry oxygen saturation and arterial blood oxygen saturation in patients with heart failure with reduced ejection fraction (HFrEF). In this study, we therefore evaluated the reliability of oxygen saturation measurements obtaining by pulse oximetry and arterial oxygen analysis in patients with HFrEF. Pulse oximetry measurements were compared with a more accurate method of arterial oxygen saturation.

MATERIAL and METHODS

Patient's selection

This study was conducted in a high volume tertiary heart center. We enrolled all patients in the study if the chief physician ordered an atrial blood gas. Included in this prospective study was 34 consecutive patients who were admitted with the diagnosis of HFrEF. The inclusion criteria were as following; being older than 18 years, providing an informed consent, and without having significant comorbidities. The exclusion criteria included the existence of impalpable radial arteries or inconvenient vascular structures for arterial blood sampling, having hemodynamic compromise, the presence of inotrope use, anemia, infection, acute renal failure, pneumonia, and chronic obstructive pulmonary disease. The baseline

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demographics, clinical characteristics, New York Heart Association functional class, medication usages, echocardiographic data, and laboratory findings of patients were collected from electronic database of our hospital. All patients in the study received the standard medical treatment according to the latest HF guideline of European Society of Cardiology. The study was approved by ethics committee of the Medipol University School of Medicine (approval number: 10840098-604.01.01-E.61050-880).

Echocardiographic and laboratory examination

All blood samples were obtained in the first morning following admission. Biochemical parameters were measured by using Roche Cobas 6000 biochemistry auto-analyzer device. Arterial samples were withdrawn from the radial artery through a heparinized syringe and were carried to the laboratory. Simultaneously, fingertip pulse oximetry measurements were obtained on the same side with the standard finger sensors. G-life pulse Fs10E oximetry type was used after calibrating with the normal patient findings. All arterial blood sample results were obtained within 15 minutes. Multiple measurements were obtained from some patients to calibrate the device accuracy. The mean value recorded for patients whom had multiple results.

Standard echocardiographic evaluation was performed by an experienced cardiologist within 24-48 h following admission. The left ventricle ejection fraction was estimated using the modified Simpson method. Systolic pulmonary artery pressure was calculated according to the Bernoulli equation.

Statistical analysis

SPSS (SPSS Inc., Chicago, IL, USA) version 20.0 was used to analyze the data. Continuous variables were presented as mean ± standard deviation (mean±SD) and the categorical variables were expressed as number and percentage (%). The agreement between pulse oximetry O2 saturation and arterial O2 saturation was assessed by Bland Altman. The strength of association was determined by Pearson correlation. A p value < 0.05 was considered to be statistically significant.

RESULTS

In total, 34 patients (the mean age was 70.7 ± 10.9, 44.8 % of all cases were male) were firstly included in the study. We excluded 5 patients from the study (2 of them had diagnosis of acute renal failure, 1 patient had a missing data, and the remaining patients had diagnosis of pneumonia). The final cohort was consisted of 29 HFrEF patients.

The clinical characteristics, echocardiographic, and laboratory data of all patients were represented in Table 1. In the present research, 26 patients had ischemic HF and 3 patients had non-ischemic HF. The mean EF of the study was 29.6 ± 5.5. We observed that the mean pulse oximetry O_2 saturation and arterial O_2 saturation in the

Table 1.Baseline clinical, laboratory and echocardiographic features of the study population

Age, years	70.7±10.9
Gender, male (n)	44.8% (13)
Clinical characteristics	
Body mass index, kg/m^2	28.2±4.5
NHYA class 3-4, (n)	60.7% (17)
NHYA class 1-2, (n)	39.3% (11)
Ischemic heart failure, (n)	89.7% (26)
Non-ischemic heart failure, (n)	10.3% (3)
Hypertension, (n)	27.6% (8)
Diabetes mellitus, (n)	25.9% (7)
Chronic renal failure, (n)	35.7% (10)
Obesity, (n)	10.3% (3)
Atrial fibrillation,(n)	30% (12)
Heart rate, bpm	86.4±17.4
BP, mmHg	
Systolic	114.7±19.5
Diastolic	70.6±11.9
Pulse oximetry SO_2	92.8±4.4
Arterial SO_2	93±5.2
V_{po2}	34.2±5.9
V_{pco2}	60.7±13.7
V_{HCO3}	26.3±4.6
Laboratory findings	
Blood urea nitrogen, mg/dL	75.4±40.5
Creatinine, mg/dL	1.6±0.6
Hemoglobin, mg/dL	12.3±2.1
Hematocrit, %	38±6
Aspartate aminotransferase, U/L	35±39
Alanine aminotransferase, U/L	46±43
Brain natriuretic peptide, ng/mL	5920±1580
Echocardiographic findings	
Left ventricle diastolic diameter, mm	61.8±5.8
Left ventricle systolic diameter, mm	50.4±7.3
Ejection fraction, %	29.6±5.5
Pulmonary artery systolic pressure, mmHg	21±14.9
Left atrium diameter, mm	51.2±7.8
Moderate-severe MR, (n)	24.1% (7)
Moderate-severe TR, (n)	20.7% (6)

Continuous variables are presented as mean ± SD or median, nominal variables presented as frequency (%).
Abbreviations: MR; mitral regurgitation, TR; tricuspid regurgitation

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study were 92.8 ± 4.4 and 93 ± 5.2, respectively. The mean V_{po2}, V_{pco2}, and V_{HCO3} were 34.2±5.9, 60.7±13.7, and 26.3±4.6 respectively.

Figure 1 shows a 95% limits of agreement between the methods. According to the Bland Altman method, the range of agreement limits were from 7.4025 to -7.8617, and the t bias (mean difference) between the pulse oximetry SO_2 saturation and arterial SO_2 saturation was -0.2296. As for the plot of unit values, this bias was not significant ($p = 0.23$).

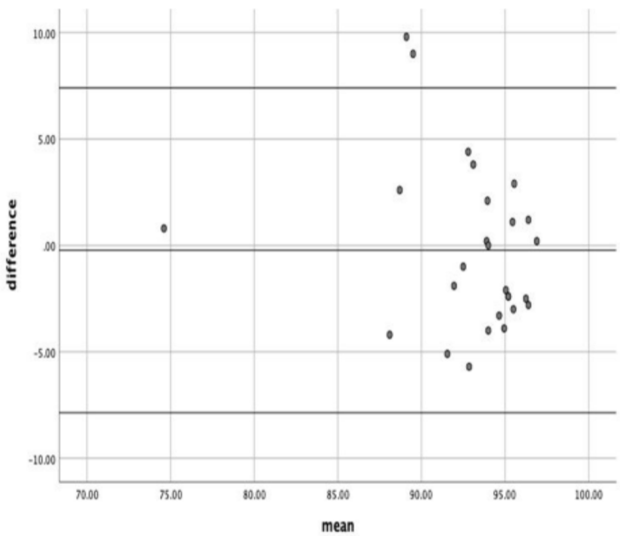

Figure 1. Bland and Altman plot, with the representation of the limits of agreement (dotted line) from -1.96s to +1.96

The correlation was significant between the methods ($p < 0.001$). According to Pearson analysis as shown Figure 2, a linear correlation was detected and the correlation coefficient was $r = 0.683$.

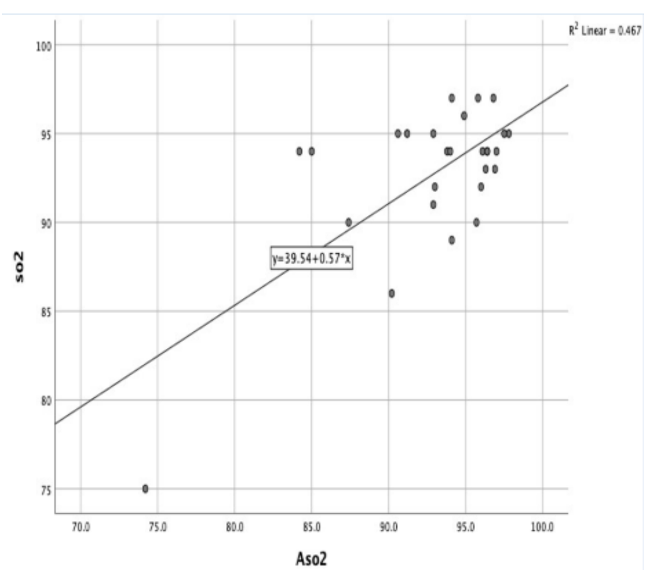

Figure 2. Pearson correlation of pulse oximetry SO2 and arterial SO_2

DISCUSSION

Arterial blood gas sampling is quintessential in guiding clinical treatment such as hospitalization, mechanical ventilator support or diuretic therapy in HF patients. However, obtaining arterial blood gas sample can be difficult, and it sometimes cause some complications, including local hematoma or infection on vascular puncture site. In some studies, pulse oximetry has been shown to be a useful for substitute of arterial blood oxygen saturation in intensive care units or emergency departments. Therefore, pulse oximetry is recommended to decrease amount of complications on vascular puncture site and to decrease economic cost (5-8).

The presence of anemia, peripheral vasoconstriction, hypotension or inotrope use may affect pulse oximetry values in patients with HF. In particular, pulse oximetry measurements may be unreliable due to low cardiac output and decreased tissue perfusion among these patients. Moreover, circulatory failure may effect peripheral oxygenation which may cause inaccurate fingertip pulse oximetry measurements. Based on these assumptions, some studies have suggested that pulse oximetry would not be an accurate method to obtain oxygen saturation in patients with impaired hemodynamics or using vasoactive agents (9). Therefore, our study focused on the specific group of HF patients without any known secondary co-morbidities including severe hemodynamic compromise, inotrope use or infection.

A previous study, which included patients with acute pulmonary edema, demonstrated that the Bland and Altman plot for arterial SO_2 and pulse oximetry SO_2 showed a mean bias 0.6 and a low accuracy in comparison between SO_2 and aSO_2 was found (5). However, the average bias (-0.209) for our study was close to zero, which means the two methods were systematically producing close results. This finding could be related to inclusion of stabilized patients with HFrEF in our study. In most of the studies, higher accuracy was found in pulse oximetry SO_2 values when the arterial SO_2 is not extremely low, which was similar with our findings (10,11). A significant bias and a lower sensitivity was found when arterial $SO_2 < 90\%$ (5,12).

Some studies have revealed that a greater bias exists in patients using vasoactive agents, with septic shock or with chronic obstructive lung disease (9,13,14). In addition to this, in critically ill patients, venous SO_2 in addition to pulse oximetry is recommended for accurately predicting arterial oxygen saturation (15). However, in our study, such patients were not present and a linear, positive, and strong relation was detected by Pearson correlation analysis. Based on the study findings, we may suggest that pulse oximetry SO_2 is an acceptable substitute for the arterial SO_2 in patients with HFrEF. However, as our data was relatively small, prospective studies with a large groups of patients are needed to confirm our results.

LIMITATION

Although some studies showed that the types of pulse oximeters may affect the agreement with the arterial blood oxygen saturation, we did not evaluate the results with different types of oximetry. In addition to this, our study was conducted in a small groups of patient population, which may also have an effect on the results. The study results might be not true for all patients with HF because we selected only patients with HFrEF.

CONCLUSION

This study has proved that the pulse oximetry SO_2 is statistically acceptable substitute for the arterial SO_2 in patients with HFrEF. Based on our results, we may suggest that pulse oximetry SO_2 may be very useful in HFrEF patients who are having inconvenient arterial structure or are under treatment of anticoagulants.

Competing interests: The authors declare that they have no competing interest.

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Ethical approval: The study was approved by ethics committee of the Medipol University School of Medicine (approval number: 10840098-604.01.01-E.61050-880).

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