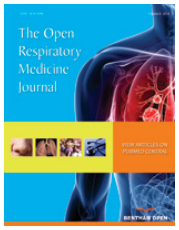

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RESEARCH ARTICLE

Effect of the Fraction of Inspired Oxygen on Intermittent Central Venous Oxygen Saturation Measurements

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Abstract:

Background:

Central venous oxygen saturation ($ScvO_2$) is an essential test readily performed both by medical and nursing personnel in a critical care setting. It gives information on the patient‘s oxygen supply, oxygen consumption, and cardiac output. It plays an important role in early goal-directed treatment.

Objectives:

This study was planned to assess the effect of different fractions of inspired oxygen (FiO_2) levels on central venous oxygen saturation for consideration during the evaluation of central venous oxygen saturation.

Methods:

This interventional cross-over study enrolled 60 critically ill, nonmechanically ventilated patients. Blood samples were repeatedly drawn from the distal end of the central venous catheter for blood gas analysis after administration of 30%, 40%, and 50% FIO_2 respectively.

Results:

The results showed that increasing FiO_2 from 30% to 40% resulted in a mean increase in $ScvO_2$ of 6.2%. While increasing FiO_2 from 40% to 50% resulted in a mean increase in $ScvO_2$ of 3.2%. A significant increase in $ScvO_2$ with changes in FiO_2 levelwas recorded among patients in shock or patients with pneumonia (from 30% to 50%, p=0.002 in shock patients and from 30% to 40%, p=0.02 in patients with pneumonia).

Conclusion:

Increasing FiO_2 resulted in a substantial rise in $ScvO_2$. $ScvO_2$ changes in response to a therapeutic challenge should be interpreted at constant FiO_2 level, especially in patients with pneumonia.

Keywords: Venous oxygen saturation, Central venous oxygen saturation, FIO_2, $ScvO_2$, Pneumonia, Respiratory failure.

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1. INTRODUCTION

The oxygen content of blood returning to the right side of the heart after perfusing the entire body is measured by venous oxygen saturation (S_vO_2) [1]. The hemoglobin saturation of blood in the superior vena cava and proximal pulmonary artery is referred to as central ($Scvo_2$) and mixed venous oxygen saturation (S_vO_2), respectively [2]. $ScvO_2$ is a vital measurement that can be performed by medical and nursing personnel in a critical care setting. It provides an understanding of the patient‘s oxygen delivery, oxygen consumption, and cardiac output [2]. When taken and evaluated properly, it plays an important role in the early goal-directed treatment and has been associated with reduced mortality [3]. A $ScvO_2$ > 70% or mixed venous oxygen saturation (SvO_2) >65% is indicated for septic and non-septic patients. [4]

Shock is defined as global cellular and tissue hypoxia secondary to either decreased systemic oxygen delivery (DO_2), systemic oxygen consumption (VO_2), inadequate oxygen utilization, or combined. A decrease in DO_2 is compensated for

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by an increase in VO_2, thereby preventing tissue hypoxia. Tissue hypoxia and lactic acidosis begin when a 'critical' DO_2 level is reached, and no more oxygen can be taken [1]. Untreated tissue hypoxia is associated with an increase in morbidity and mortality [5]. Therefore, an accurate diagnosis of global tissue hypoxia is critical. Physical examination, vital signs, measurement of central venous pressure, and urine output are all relevant but are still insufficient for detecting global tissue hypoxia [5].

The measurement of mixed venous oxygen saturation in the pulmonary artery (S_vO_2) has been recommended as an indirect indicator of tissue oxygenation. However, the use of the pulmonary artery catheter has become somewhat unpopular. By contrast, insertion of a central venous catheter into the superior vena cava is considered standard care in critically ill patients. The assessment of central venous oxygen saturation ($ScvO_2$), similar to SvO_2, has been recommended for detecting global tissue hypoxia [5, 6].

$ScvO_2$ levels can be monitored on an as-needed basis (intermittently) by taking blood from the central line for blood gas analysis. It may also be monitored in real-time (continuously) using a fiberoptic catheter equipped with reflection spectrophotometry. The saturation level is shown on an oximetry meter and is updated every 2 seconds [1].

Cardiac output, plasma hemoglobin concentration, blood transfusions, and blood volume are the most important factors influencing $ScvO_2$ and may lead to misinterpretation of $SCvO_2$ [7]. Therefore, this study was planned to assess the effect of different fractions of inspired oxygen (FiO_2) levels on central venous oxygen saturation for consideration during the evaluation of central venous oxygen saturation.

2. MATERIALS AND METHODS

This interventional cross-over study included 60 critically ill, nonmechanically ventilated patients admitted to the respiratory critical care unit of the Chest Medicine Department at Mansoura University. All included patients already had a central line. This study was conducted within the required ethics guidelines of the Mansoura Institutional Research Board ethics committee (code number: R.21.10.1485). Informed written consent was obtained from the included patients.

Blood samples were repeatedly drawn from the distal end of the central venous catheter for blood gas analysis. The samples were aspirated into a heparinized blood gas syringe 30 min after administration of 30%, 40%, and 50% FiO_2 respectively. The samples were then analyzed in a blood gas analyzer, which was regularly calibrated.

Statistical analysis of the data was performed using SPSS V.16. A repeated-measure ANOVA with a Greenhouse-Geisser correction and post hoc tests using the Bonferroni correction were conducted.

3. RESULTS

A total of 60 patients (mean age 61±11 years) were included in the study. Males represented 58.6% (35) of the patients. In total, 37.9% of the patients had pneumonia, and 19% were hemodynamically unstable (Table **1**). A subclavian catheter was inserted in 27 patients, and 33 patients had jugular catheters. All patients were spontaneously breathing, and oxygen was delivered *via* a simple facemask. We recorded $ScvO_2$ after 30 min of each increase in the FiO_2.

Table 1. Characteristics of studied patients.

-	No	Percent (%)
Gender: Male	35	58.6
Female	25	41.4
Shock	11	19.0
Anemia	21	36.2
Pneumonia	22	37.9
age	mean± SD	61.6± 11

The results of this study showed that increasing FiO_2 from 30% to 40% resulted in a mean increase in $ScvO_2$ of 6.2%, whereas increasing FiO2 from 40% to 50% resulted in a mean increase in $ScvO_2$ of 3.2%. A repeated-measures ANOVA with a Greenhouse-Geisser correction determined that the mean $ScvO_2$ differed significantly between different levels of FiO_2 ($F(1.710, 83.8) = 9.23$, $p < 0.001$). Post hoc tests using the Bonferroni correction revealed a statistically significant increase in $ScvO_2$ when FiO_2increased from 30% to 40% (64.7 ± 15.85 *vs*. 70.998 ± 13.8, p=0.011) and from 30% to 50% (64.7 ± 15.85 *vs*. 74.098 ± 10.19, p = 0.003). However, the increase in $ScvO_2$ when $FiO_2$was changed from 40% to 50% (70.998 ± 13.8 *vs*. 74.098 ± 10.19, p = 0.33) was insignificant (Table **2**).

Table 2. Overall association between $ScvO_2$ and 30%, 40%, and 50% of FiO_2.

-	Mean	Std. Deviation	F	Significance	Partial Eta Squared
ScvO2 **30**[b,d]	64.7500	15.85000	F (1.766, 83.8) = 9.230	<0.000	0.159
ScvO2 **40**[b,c]	70.9980	13.84906			
ScvO2 **50**[c,d]	74.0980	10.19781			

Similar superscripted letters indicate p value by post hoc Bonferroni test b=0.01, c=0.331, d=0.003

A significant increase in $ScvO_2$with changes in $FiO_2$was found among patients in shock and those with pneumonia (from 30% to 50%; p = 0.002 in shock patients and from 30% to 40%; p = 0.02 in patients with pneumonia). However, a nonsignificant increase in $ScvO_2$ was found when FiO_2 was changed in hemodynamically stable and anemic patients and in those without pneumonia (Table **3**).

Table 3. Association between $SCVO_2$ at different FIO_2 levels and characteristics of studied patients.

Factor	scvo30 mean (SD)	scvo40 mean (SD)	scvo50 mean (SD)	F	Overall Significance	Pairwise Significance	Partial Eta Squared
Shock	51(14.4) [a]	59.8 (11.1)	72.8(8.5) [a]	F (2,16) =14.2	<0.001	a= 0.002	0.639
No shock*	67.3 (15.9)	73 (14.1)	72.6 (11.2)	F (1.6,48.4) =2.02	0.152		0.06
Anemia	63.4 (19.7)	69.5 (17.4)	74.2 (12.4)	F (2,34) =2.7	0.08		0.138
No anemia*	64.2 (14.6)	70.5 (11.9)	71.3 (8.9)	F (1.6,33.5) =3.27	0.061		0.135
Pneumonia	60.1 (14.5) [a]	65.9 (9.2) [a]	70.5 (10)	F (2,34) =	0.005	a=0.029	0.269
No Pneumonia	66.9 (17.5)	74.1 (16.4)	74.4 (10.5)	F (2,46) =2.2	0.12		0.088

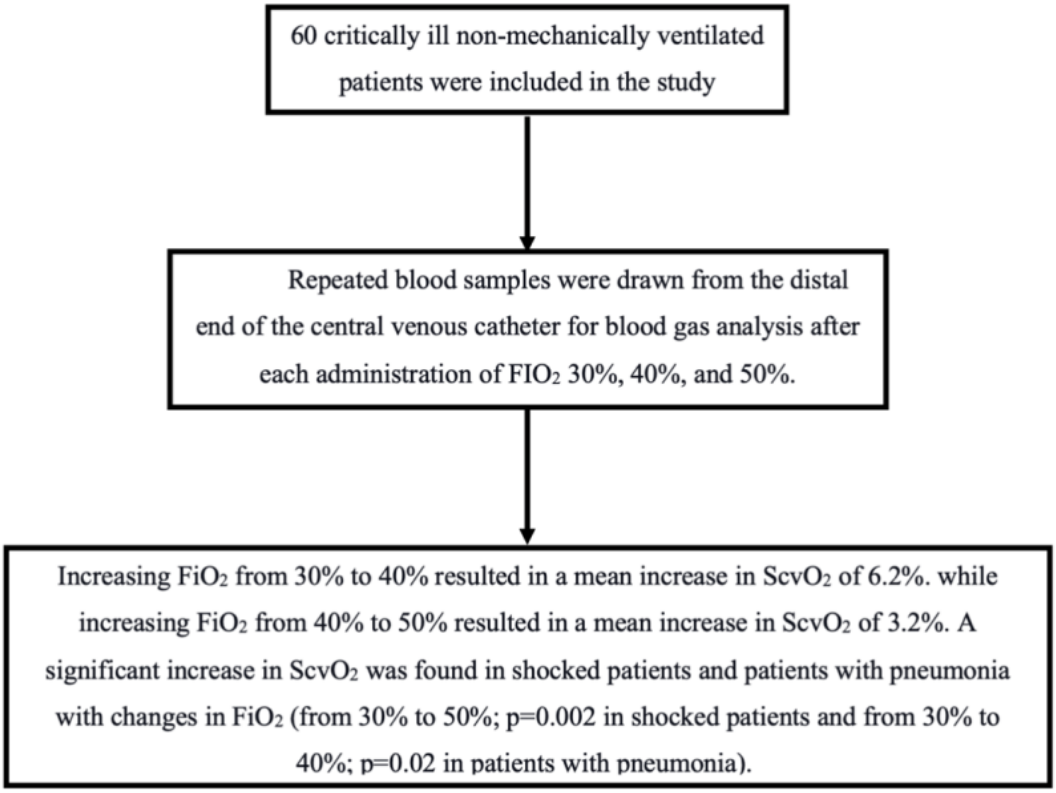

Fig. (1). A graphical abstract that illustrates the results of the study.

4. DISCUSSION

Proper hemodynamic monitoring of critically ill patients is still in some way challenging.

$ScvO_2$ represents a surrogate parameter for the evaluation of the O_2 demand/supply adequacy. Therefore, there is extensive interest in the utilization of $ScvO_2$ to guide fluid and inotrope administration [8]. A previous study by *Rivers et al.* [9] on septic patients revealed a decline in morbidity and mortality in the early goal-directed therapy in which $ScvO_2$ was adjusted to more than 70%. In addition to cardiac output, $ScvO_2$ is also affected by a range of factors that affect blood oxygen content and tissue oxygen consumption. The effects of changing FiO_2 levelson $ScvO_2$, *i.e*. the highlight of the present study, were not considered by *Rivers et al.* [9].

The results of this study showed that increasing FiO_2 from 30% to 40% resulted in a mean increase in $ScvO_2$ of 6.2%, while increasing FiO_2 from 40% to 50% resulted in a mean increase in $ScvO_2$ of 3.2%. *Jee and White* [10] also investigated the effect of increasing FiO_2 to 100% on $ScvO_2$ in critically ill patients and found that the mean increase in $ScvO_2$ was 6.7%.

Nam et al. [11] reported that SvO_2 increased by ≥5% in more than three-quarters of FiO_2 increases from 30% to 80% or 50% to 100% during cardiac surgery and by ≥10% in the remaining one-quarter of FiO_2 changes. Whereas HB remained almost fully saturated, PaO_2 changed remarkably as FiO_2 was changed. *Legrand et al*. [7] concluded that PaO_2 should not be overlooked while considering the $ScvO_2$ value as a therapeutic goal, as the author's observed that $ScvO_2$ rose from 71% to 83% after increasing FiO_2 [7].

In patients with or without anemia, a nonsignificant increase in $ScvO_2$ was found with changing FiO_2 in this study. This result is compatible with that of *Nam et al.* [11], who found a nonsignificant association between Hb concentration and ΔSvO_2.

A significant increase in ScvO2 with changes in FiO_2 was found among patients in shock and those with pneumonia in this study. This observation may have significant implications for the interpretation of $ScvO_2$ data in clinical practice. However, the cause of the shock was not identified in this study.

CONCLUSION

Increasing FiO_2 was linked to a substantial rise in $ScvO_2$, which would consequently affect the interpretation of $ScvO_2$ data. Interpretation of variations in $ScvO_2$ in response to a therapeutic challenge should be performed at constant FiO_2, especially in patients with pneumonia.

LIST OF ABBREVIATIONS

$ScvO_2$	=	Central Venous Oxygen Saturation
FiO_2	=	Fractions of Inspired Oxygen
DO_2	=	Decreased Systemic Oxygen Delivery
VO_2	=	Systemic Oxygen Consumption

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted within the required ethics guidelines of the Mansoura Institutional Research Board Ethics Committee, Egypt (code number: R.21.10.1485).

HUMAN AND ANIMAL RIGHTS

No animals were used for the studies that are the basis of this research. This research was conducted on humans in accordance with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

Informed written consent was obtained from included patients.

STANDARDS FOR REPORTING

STROBE guidelines and methodology were followed.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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