Mixed venous versus central venous oxygen saturation in patients undergoing on pump beating coronary artery bypass grafting

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ABSTRACT

Objective: To examine the validity of central venous oxygen saturation ($ScvO_2$) as a numerical substitution of mixed venous oxygen saturation (SvO_2) in adult patients undergoing normothermic on pump beating coronary artery bypass grafting (CABG). **Materials and Methods:** Prospective clinical observational study was done at King Khalid University Hospital, King Saud University, Riyadh, Kingdom of Saudi Arabia. Thirty four adult patients scheduled for coronary artery surgery were included. Patients were monitored by a pulmonary artery catheter (PAC) as a part of our routine intraoperative monitoring. SvO_2 and $ScvO_2$ were simultaneously measured 15 minutes (*T*1) and 30 minutes (*T*2) after induction of anesthesia, 15 and 30 minutes after initiation of cardiopulmonary bypass (*T*3 and *T*4), and 15 and 30 minutes after admission to intensive care unit (*T*5 and *T*6). **Results:** $ScvO_2$ showed higher reading than SvO_2 all through our study. Our results showed perfect positive statistically significant correlation between SvO_2 and $ScvO_2$ at all data points. Individual mean of difference (MOD) between both the readings at study time showed MOD of 1.34 and 1.44 at *T*1 and *T*2 simultaneously. This MOD was statistically insignificant, but after on pump beating normothermic bypass was initiated; MOD was 5.2 and 4.4 at *T*3 and *T*4 with high statistical significance. In ICU, MOD continues to have high statistical significance, MOD was 6.3 at *T*5 and at *T*6 it was 4.6. **Conclusions:** In on pump beating CABG patients; $ScvO_2$ and SvO_2 are not interchangeable numerically. $ScvO_2$ is useful in the meaning of trend; our data suggest that $ScvO_2$ is equivalent to SvO_2, only in the course of clinical decisions as long as absolute values are not required.

Key words: *Coronary artery bypass grafting, mixed venous oxygen saturation, coronary artery bypass grafting, mixed venous oxygen saturation, central venous oxygen saturation*

DOI: 10.4103/1658-354X.65129

INTRODUCTION

Mixed venous oxygen saturation (SvO_2) is a valuable measurement in hemodynamically unstable patients during cardiac surgery.[1,2] SvO_2 has been used to assess to what extent the cardiopulmonary system meets the metabolic demands of the various tissues and to provide an index of tissue oxygenation.[3] Furthermore, it allows calculation of tissue oxygen consumption, oxygen extraction ratio, and the degree of pulmonary venous admixture.[4] However, SvO_2

measurement is obtained only from a correctly positioned pulmonary artery catheter (PAC).

Significant complications are associated with the use of a PAC.[5,6] As such, central venous oxygen saturation ($ScvO_2$) represents an attractive alternative to SvO_2 because central venous catheterization is easier and less invasive than pulmonary artery (PA) catheterization.[7]

The clinical applicability of substituting $ScvO_2$ for SvO_2 in different clinical situations is still not fully studied. Open heart surgery is a unique clinical situation where there is a great variation during the surgery in hemodynamic and filling indices.

In a previous study,[8] we aimed to examine the correlation between $ScvO_2$ sampled from a standalone central venous line (CVL) and SvO_2 sampled from PAC port, to test the validity of the clinical applicability of substituting $ScvO_2$ from CVL for SvO_2 in adult patients with poor myocardial function undergoing open heart coronary artery bypass grafting surgery (CABG).[8] In the current study, we are testing the same hypothesis in patients with normal functioning myocardium undergoing CABG using the on pump beating technique, while measuring the $ScvO_2$ from a proximal PAC port.

MATERIALS AND METHODS

After obtaining approval from the Institutional Review Board at the College of Medicine, King Saud University, Riyadh, KSA, and informed consent from each participant, we studied 34 patients scheduled to undergo CABG using on pump beating normothermic cardiopulmonary bypass.

The present study is a prospective observational study. Thirty four adult patients of either sex, aged above 40 years, suffering from coronary heart disease with normal myocardial function, scheduled for elective CABG surgery were included in the study.

A standardized balanced anesthetic technique was used for all the patients; patients were premedicated with lorazepam 2 mg orally at the night of surgery and morphine 0.1 mg/kg IM preoperatively. On receiving the patient in operating room, standard monitoring was instituted. Peripheral venous as well as radial artery cannulae were inserted. Induction is with sufentanil 1–1.5 μg/kg, midazolam 0.05–0.1 mg/kg, and rocuronium 0.9 mg/kg, then a maintenance infusion of the same induction agents, that is, sufentanil 0.2 μg/kg/h, midazolam 1.5 μg/kg/h and rocuronium 0.5 mg/kg/h supplemented with sevoflurane was given as required. Induction doses as well as anesthetic maintenance supplementation were guided by BIS® monitoring (Aspect *medical Systems, inc,* Norwood, Massachusetts, USA), and signs of lack of analgesia correlated with hemodynamic changes were managed as appropriate. A PAC was inserted after induction of anesthesia enabling monitoring of SvO_2, $ScvO_2$ as well as other derived parameters. The lungs were mechanically ventilated with a tidal volume of 8 mL/kg and FiO_2 of 0.4 oxygen in air mixture, while ventilatory rate was adjusted to maintain a $PaCO_2$ of 32–36 mmHg.

A 7.5F PAC (Edwards Lifesciences; Irvine, CA, USA) that was 110 cm in length and had the right atrial lumen positioned 30 cm from the tip was inserted through the internal jugular vein using a percutaneous 8.5F sheath introducer (Edwards Lifesciences). A pressure tracing obtained from the proximal PAC port was used to ascertain correct positioning in the right atrium (RA). Postoperative portable chest radiograph and the presence of PA pressure tracings confirmed the location of the distal port in the PA.

Immediately after the insertion of the PAC, each patient had one set of paired blood samples drawn in random order simultaneously from the distal and proximal ports of PAC. The first 2 mL blood drawn for each sample was discarded to prevent contamination with flushing fluid. Blood was sampled from distal PAC port while the catheter balloon deflated. We then measured the pulmonary artery occlusive pressure (PAOP) and cardiac output (CO) by the thermo dilution method as well as other hemodynamic calculations.

Previous data were collected 15 and 30 minutes after induction of anesthesia (*T*1, *T*2), 15 and 30 minutes after initiation of cardiopulmonary bypass (*T*3, *T*4) and 15 and 30 minutes postadmission to intensive care unit (*T*5 and *T*6).

Blood samples were drawn simultaneously from the PA and RA at six different data points mentioned. A standard volume of 1 mL blood was obtained from each site, and oxygen saturations per blood sample were determined using the blood gas analyzer (QS 50®; Radiometer, Copenhagen, Denmark).

All surgeries were done by the same surgeon, using the on pump beating normothermic cardiopulmonary bypass.

Data analysis

Data were analyzed using statistical software package (Graph Pad In Stat® version 3.00 for Windows, Graph Pad Software Inc., San Diego, CA, USA) and presented as numbers, mean (standard deviation [SD]), or ratio. Data were compared using the parametric or the nonparametric versions of analysis of variance (ANOVA) followed by the appropriate *post hoc* analysis if significance was detected. *P* values <0.05 were considered significant.

Demographic and hemodynamic data were compared using the Student's *t*-test with levels of significance adjusted according to the method of Bonferroni for multiple comparisons. $P < 0.05$ is deemed to denote a significant difference.

The correlation between SvO_2 and $ScvO_2$ was evaluated by linear regression analysis and Pearson test followed by the *F* test. Mean of difference (MOD) between simultaneously measured SvO_2 and $ScvO_2$ individual values were calculated. The Student's *t*-test was used to determine whether the mean difference was significantly different from zero.

RESULTS

Patients' demographic and operative data are shown in Table 1. The measured hemodynamic parameters and hemoglobin concentration values are listed in Table 2. Other parameters assessed such as Cardiac Index, PAOP and CVP were not applicable during bypass (*T*3 and *T*4).

$ScvO_2$ showed higher values than SvO_2 all through our study [Table 3]. Data showed perfect positive statistically significant correlation between SvO_2 and $ScvO_2$ at all study times, individual MOD between both the readings at study time showed MOD of 1.34 and 1.44 at *T*1 and *T*2 simultaneously, this MOD was statistically insignificant; but after bypass was initiated, MOD was 5.2 and 4.4 at *T*3 and *T*4 with high statistical significance; after bypass MOD continues to have high statistical significance, it was 6.3 at *T*5 and at *T*6 it was 4.6 [Table 3].

Table 1: Demographic and operative data

Number of patients	34
Age (years)	57.1 ± 5.2
Sex M/F (*n*)	25/9
Preoperative Hb% (g/dL)	12.1 ± 1.57
No. of grafts	2.9 ± 0.81
LVEF (%)	47.41 ± 5.92
CPB time (minutes)	109.4 ± 18.51

Data are expressed as mean ± SD.

DISCUSSION

In the present study, blood was taken from the RA to be representative of whole body central venous blood. Presumably, this position placed the $ScvO_2$ sampling site sufficiently distal into the RA to allow for the mixing of blood from the superior and inferior venacavae.

Results showed a lower value of SvO_2 compared to $ScvO_2$, a possible explanation for the decrease in SO_2 from $ScvO_2$ to SvO_2 is the myocardial extraction of O_2 as blood flows through the right ventricle into the PA. Although, to our knowledge, the rate of O_2 diffusion from ventricular blood into the myocardium has not been quantified, we consider this possibility unlikely. A more likely hypothesis is that atrial blood, as it moves toward the PA, mixes with blood of lower O_2 content. It is also possible that decrease

Table 2: Hemodynamic parameters and hemoglobin concentrations at the different data points

	*T*1	*T*2	*T*3	*T*4	*T*5	*T*6	*P* value
SaO_2 (%)	99.21 ± 1.23	99.34 ± 0.81	99.49 ± 0.92	99.59 ± 0.72	99.3 ± 0.94	99.21 ± 0.69	NS
CI (L/min/M²)	3.32 ± 1.22	3.13 ± 1.14	NA	NA	4.32 ± 0.89	3.89 ± 0.81	NA
PAOP (mmHg)	17.12 ± 5.93	18.32 ± 5.16	NA	NA	13.33 ± 5.9	14.13 ± 5.44	NA
CVP (mmHg)	14.23 ± 8.15	11.62 ± 6.26	NA	NA	13.96 ± 7.34	12.93 ± 8.52	NA
Hb (g/dL)	12.41 ± 1.7	12.1 ± 1.42	10.1 ± 2.32	8.98 ± 2.56	9.67 ± 1.32	10.2 ± 3.44	<0.001

Data are expressed as mean ± SD, significant ($P < 0.05$) NA, not applicable; NS, not significant.

Table 3: Correlation between SvO_2 and $ScvO_2$ at the different data points

	SvO_2	$ScvO_2$	MOD	*P* value (t test)	Correlation coefficient (*r*)	*P* (*F* test)
*T*1	80.98 ± 5.26	82.32 ± 6.035	1.34	0.2140	0.752	0.001
*T*2	82.93 ± 5.17	81.5 ± 3.47	1.43	0.1760	0.7914	<0.0001
*T*3	78.1 ± 6.31	83.3 ± 5.31	5.2	<0.0005	0.6301	0.0099
*T*4	80.8 ± 6.1	85.2 ± 4.93	4.4	0.0017	0.687	0.0009
*T*5	79.12 ± 5.91	85.42 ± 6.3	6.3	<0.001	0.7901	0.0001
*T*6	76.7 ± 5.96	81.3 ± 5.67	4.6	0.0018	0.6901	0.0117

Data are expressed as mean ± SD, significant ($P < 0.05$).

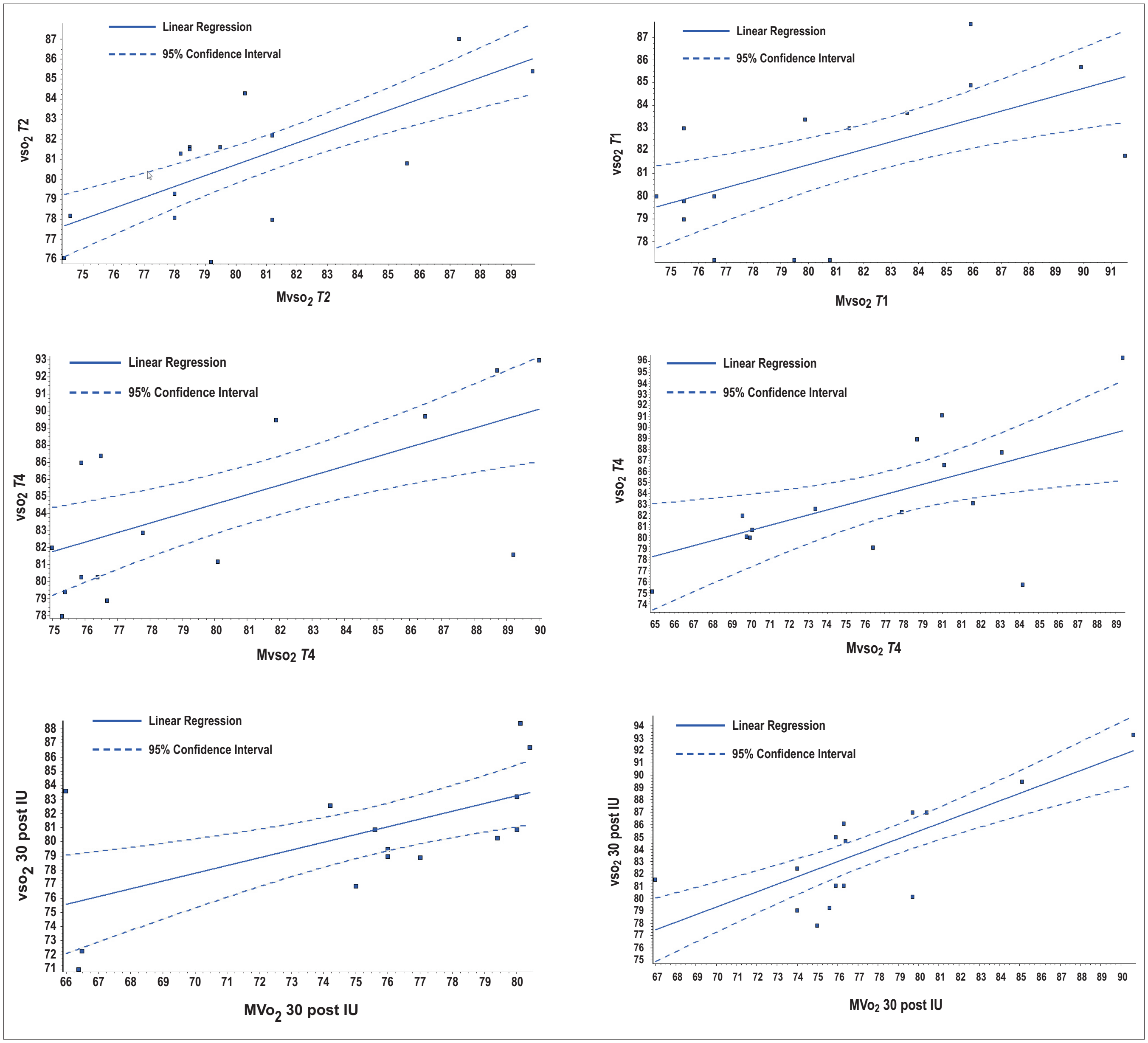

Figure 1: The correlation between SvO_2 and $ScvO_2$ in all data points

in SvO_2 resulted from blood mixing with blood draining from coronary sinus in RA and the Thebesian veins in the right ventricle.[10]

Experimental studies in animals showed an excellent correlation between $ScvO_2$ and SvO_2. Reinhart *et al.*[11] found a Spearman correlation coefficient of 0.97 in anesthetized dogs over a broad range of cardio-respiratory conditions, including hypoxia, hemorrhage, and resuscitation. Schou *et al.*[12] also found a correlation coefficient of 0.97 between $ScvO_2$ and SvO_2 in pigs that had been subjected to conditions of graded hypoxemia. Of note, both studies found SvO_2 to be consistently lower than $ScvO_2$.

Our data showed perfect positive statistically significant correlation between SvO_2 and $ScvO_2$ at all data points [Table 3 and Figures 1 a-f].

In the present study, individual mean of difference between both the readings at data points showed MOD of 1.34 and 1.44 at *T*1 and *T*2 simultaneously. This MOD was statistically insignificant, meaning that they are interchangeable numerically; but after bypass was initiated, MOD was 5.2 and 4.4 at *T*3 and *T*4 with high statistical significance. In the ICU; MOD continues to have high statistical significance, MOD was 6.3 at *T*5 and 4.6 at *T*6. The poor agreement between the values of SvO_2 and $ScvO_2$ after initiation of cardiopulmonary bypass presented here may be secondary to the acute changes in hemodynamics accompanying the shift to CPB with hemodilution and the nonpulsatile flow pattern. Moreover, catheter position might be altered while cannulating the RA for bypass and by myocardial manipulation during surgery. This agrees with other studies[13,14] comparing measures of $ScvO_2$ and SvO_2 in critically ill patients. Similarly, poor agreement results appeared with other studies comparing SvO_2 and $ScvO_2$ in hemodynamically unstable patients. These studies were performed outside the context of cardiac surgery, with heterogeneous groups of patients in septic,[15] cardiogenic,[16] and neurogenic shock,[17] and all of them reported a poor agreement between SvO_2 and $ScvO_2$ individual values. Schmitz *et al.*[17] showed also that patients with normal cardiac index values, $ScvO_2$, could not be substituted for SvO_2 after cardiac surgery with cardiopulmonary bypass.

In our previous study,[8] we found the same pattern of oxygen saturation reduction while the blood moves from RA to the PA and a positive correlation between the readings obtained from the measured samples, but we could not find relation between RA and PA data.

Limitations of the study

In spite of the care taken to have the PAC positioned accurately, its position is bound to be altered by the insertion of atrial cannulae for bypass, and by cardiac mobilization during surgery.

CONCLUSIONS

In CABG patients; $ScvO_2$ and SvO_2 are not interchangeable numerically as they have failed to keep insignificant MOD when normothermic CPB was used, but had strong positive and significant correlations throughout the operative course. This makes $ScvO_2$ useful in the meaning of trend; these data suggest that $ScvO_2$ is equivalent to SvO_2 in the course of clinical decisions as long as absolute values are not required.

ACKNOWLEDGEMENTS

We gratefully acknowledge the technical assistance of Mr. M Akbar Khan, Chief Cardiac Anesthesia Technician, King Fahad Cardiac Center, King Saud University, Riyadh, KSA, and Mr. Hasan Abo Kishk, Cardiac Anesthesia Technician, King Fahad Cardiac Center, King Saud University, Riyadh, KSA.

REFERENCES

1. O'Connor JP, Townsend GE. Perioperative continuous monitoring of mixed venous oxygen saturation should be routine during high-risk cardiac surgery. J Cardiothorac Anesth 1990;4:647-50.
2. Pölönen P, Ruokonen E, Hippeläinen M, Pöyhönen M, Takala J. A prospective, randomized study of goal-oriented hemodynamic therapy in cardiac surgical patients. Anesth Analg 2000;90:1052-9.
3. Nelson LD. Continuous venous oximetry in surgical patients. Ann Surg 1986;203:329-33.
4. McGrath RB. Invasive bedside hemodynamic monitoring. Prog Cardiovasc Dis 1986;29:129-44.
5. Ducatman BS, McMichan JC, Edwards WD. Catheter-induced lesions of the right side of the heart. A one-year prospective study of 141 autopsies. JAMA 1985;253:791-5.
6. McArthur CJ. Cardiovascular monitoring in sepsis: Why pulmonary artery catheters should not be used. Crit Care Resusc 2006;8:256-9.
7. Djaiani G, Karski J, Yudin M, Hynninen M, Fedorko L, Carroll J, *et al.* Clinical outcomes in patients undergoing elective coronary artery bypass graft surgery with and without utilization of pulmonary artery catheter-generated data. J Cardiothorac Vasc Anesth 2006;20:307-10.
8. Ibrahim O, Alshaer A, Elegued MA, Sheta S. Correlation between mixed venous and central venous oxygen saturation in patients undergoing CABG. Egypt Heart J 2009;61:2.
9. Edwards JD, Mayall RM. Importance of the sampling site for measurement of mixed venous oxygen saturation in shock. Crit Care Med 1998;26:1356-60.
10. Scheinman MM, Brown MA, Rapaport E. Critical assessment of use of central venous oxygen saturation as a mirror of mixed venous oxygen in severely ill cardiac patients. Circulation 1969;40:165-72.
11. Reinhart K, Kuhn HJ, Hartog C, Bredle DL. Continuous central venous and pulmonary artery oxygen saturation monitoring in the critically ill. Intensive Care Med 2004;30:1572-8.
12. Schou H, Perez de Sá V, Larsson A. Central and mixed venous blood oxygen correlate well during acute normovolemic hemodilution in anesthetized pigs. Acta Anaesthesiol Scand 1998;42:172-7
13. Krafft P, Steltzer H, Hiesmayr M, Klimscha W, Hammerle AF. Mixed venous oxygen saturation in critically ill septic shock patients. The role of defined events. Chest 1993;103:900-6.
14. Pölönen P, Ruokonen E, Hippeläinen M, Pöyhönen M, Takala J. A prospective, randomized study of goal-oriented hemodynamic therapy in cardiac surgical patients. Anesth Analg 2000;90:1052-9.
15. Faber T. Central venous versus mixed venous oxygen content. Acta Anaesthesiol Scand Suppl 1995;107:33-6.
16. Lee J, Wright F, Barber R, Stanley L. Central venous oxygen saturation in shock: A study in man. Anesthesiology 1972;36:472-8.
17. Lequeux PY, Bouckaert Y, Sekkat H, Van der Linden P, Stefanidis C, Huynh CH, *et al.* Could central venous oxygen saturation be an attractive alternative to mixed venous oxygen saturation in cardiac surgery with cardiopulmonary bypass. Eur J Anaesthesiol 2005;22:A74.

Source of Support: Nil, **Conflict of Interest:** None declared.