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Comparison of Regional Cerebral Oxygen Saturation (rSO2) and Central Venous Oxygen Saturation (ScvO2) as Predictors of Outcome in Off Pump Coronary Artery Bypass Graft (OPCABG) Surgery Patients

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Abstract

Objectives: Aim of the study was to compare central venous oxygen saturation (ScvO2) and regional cerebral oxygen saturation (rSO2) to see which of the two is better predictor of prognosis of patients undergoing off–pump coronary artery bypass grafting (OPCABG). Heart rate (HR), invasive blood pressures, and partial pressure of oxygen (pO2) have also been recorded to see if they are independent predictors of prognosis in OPCABG patients.

Materials and Methods: A total of 56 patients undergoing OPCABG were included in the study. Baseline values and intraoperative values of ScvO2, rSO2, HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP), pO2 at different time periods were recorded. Post-operatively the patients were shifted to Intensive care unit (ICU) on elective ventilation, and time to extubation since shifting to ICU were noted.

Results: The ScvO2 values after sternal closure (correlation coefficient r= -0.4821, P=0.0002), and on shifting to ICU (correlation coefficient r= -0.4575, P=0.0004) showed strong correlation with time to extubation. Similarly the rSO2 values after sternal closure (correlation coefficient r=-0.5198, P<0.0001) and on shifting to ICU (correlation coefficient r = -o.5498, P<0.0001) showed strong correlation with time to extubation. HR SBP, DBP, MAP, pO2 individually didn't show any correlation with time to extubation (P>0.05).

Conclusion: ScvO2 and rSO2 both have strong correlation with time to extubation and are capable of predicting prognosis in OPCABG patients.

Keywords: off-pump coronary artery bypass grafting, central venous oxygen saturation, regional cerebral oxygen saturation

Introduction

Coronary artery bypass grafting (CABG) has been shown to be lifesaving in patients unsuitable for coronary angioplasty. Currently, off-pump coronary artery bypass surgery (OPCAB) is done for myocardial revascularization in the majority of heart units in the developing countries for economic constrains. The role of cardiac stabilization and positioning of the heart is achieved with stabilization devices, in combination with deep pericardial traction sutures, enabling surgeon to perform multi vessel coronary revascularization in beating heart. This strategy obviates the deleterious effects of cardiopulmonary bypass associated with on pump CABG[1]. However even this procedure carries a significant risk of major complications. Associated comorbid conditions of the patient and positioning of the heart during the procedure significantly hampers oxygenation of the vital organs which post-operatively cumulates as increased risk of morbidity and mortality in terms of multiple organ system dysfunction.

In an attempt to reduce these complications numerous studies and trials have been carried out for adoption of goal directed, evidence based, haemodynamic treatment strategies. Apart from monitoring of haemodynamic parameters, certain variables of optimal cerebral perfusion have gained impetus.

Central venous oxygen saturation (ScvO2) has been suggested as one of the goal to address the issue of adequate cardiovascular circulatory function in context of cardiac surgeries[2]. It is an excellent indicator of match/mismatch between cardiac output (CO), arterial oxygen saturation, and haemoglobin (Hb) level as determinants of oxygen delivery and oxygen consumption[2].

Regional cerebral oxygen saturation (rSO2) measured by near infrared spectroscopy (NIRS) non-invasively detects brain hypoperfusion. Its primary aim is to detect cerebral oxygen demand and supply[3]. Fluctuations during intra-operative period can result in temporary brain hypoperfusion. If these periods are sustained, permanent neurological injury may ensue. Neurological injury can therefore be prevented if effective and goal oriented monitoring detects potentially harmful conditions early enough to allow initiation of effective interventions before irreversible injury has occurred.

The aim of this study is to investigate which of the two parameters either ScvO2 or rSO2 is a better predictor of prognosis in OPCABG patients, when the prognosis marker considered in this study is the "time taken for extubation of the patient" after shifting to ICU. Other parameters such as heart rate (HR), invasive blood pressure, partial pressure of oxygen in arterial blood (pO2) has been recorded to see whether these are independent predictors for prognosis of patients.

Materials and Methods

It was an Observational study with longitudinal follow up and all the consecutive subjects fulfilling the criteria was recruited in the study. So, no control was required for the study.

After getting Institutional Ethical Committee approval 56 patients undergoing elective OPCABG surgery were recruited for the study after obtaining informed written consent from them.

Exclusion Criteria of this study were patient refusal, patients with history of cerebrovascular accident with persistent neurological deficit, unilateral occlusion of carotid artery greater than 70%, bilateral occlusion of carotid artery greater than 50%, combined cardiac procedures i.e. CABG plus heart valve replacement, left ventricular ejection fraction < 30%, uncontrolled diabetes mellitus, left main coronary artery (LMCA) disease or LMCA equivalent disease, serum creatinine >2mg/dl, and if the procedure had been converted to on-pump CABG.

Pre-anaesthetic evaluation including detailed history taking, thorough physical and neurological examination, assessment of spine, airway examination were performed in all patients. Preoperative routine haematological investigations including Haemoglobin, TLC, DLC, ESR, platelet count, blood sugar (Fasting and Post Prandial), serum urea and creatinine, liver function test, chest X-ray (PA view), ECG-all 12 leads, Echocardiography and Coronary angiogram were done.

All patients were fasted overnight. On the day of surgery patient were shifted to the operation theatre. NIBP, ECG leads, SpO2 probe, NIRS sensors were attached to the patient. Arterial line was inserted in left hand under local anaesthesia. Baseline values of all variables were recorded.

Patient was pre-oxygenated with 100% oxygen for 3 mins. Induction of anaesthesia was done with inj midazolam 0.1-0.2 mg/kg, inj fentanyl 2-3 microgram/kg and inj thiopentone 4-5mg/kg. Intubation of trachea was facilitated with administration of inj rocuronium (1-1.5mg/kg) after 90secs. Central line was inserted in right internal jugular vein and pulmonary artery catheter was inserted. A pre incision value of all the variables were recorded. Patients were monitored continuously and values were recorded intermittently. Maintenance of anaesthesia was done with isoflurane, midazolam, fentanyl, and vecuronium. Inj Heparin 2 mg/kg was administered before start of grafting, and was repeated hourly as 0.5/kg to maintain Activated clotting time (ACT) between 200-300sec. After completion of grafting heparin activity was reversed by inj protamine 1.3 times the initial heparin dose. ACT was rechecked and maintained <150 sec. After end of surgery, the patients were shifted to ICU with endotracheal tube in situ. Patients were monitored in ICU as to when the patient reached the extubation criteria and the time to extubation since shifting to ICU was recorded.

The variables rSO2, ScvO2, MAP, HR, pO2 were recorded at baseline (after insertion of CVP), pre incision, after sternotomy, after each graft, after sternal closure and after shifting to ICU Time to extubation was considered as the prognosis in the study. The patients were extubated when they met the criteria for extubation as per Institutional protocol.

Preoperative and intraoperative data were collected as regional cerebral oxygen saturation (rSO2) measured by NIRS spectrometry, central venous oxygen saturation (ScvO2), partial pressure of oxygen in arterial blood (pO2), heart rate (HR), mean arterial pressure (MAP).

- Pre incision
- After sternotomy
- After each graft
- After sternal closure
- On shifting to ICU

Data was summarized by routine descriptive statistics, namely mean and standard deviation for normally distributed numerical variable, median and interquartile for skewed numerical variable and counts and percentages for categorical variables. Association between numerical variables was quantified by calculating Pearson's Rank correlation coefficient 'R' after examination for linear relation through construction of scatter plots. Strong correlations were observed, an attempt was made to build up regression equation to predict extubation time on the basis of numerical predictors.

Sample size calculation:- The purpose of this study was to explore the impact of various predictors, esp. rSO2 and ScvO2 on outcome in OPCABG patients. For the purpose of sample size we had considered 'Time to extubation' as primary outcome measure. Assuming a linear relationship between an oxygenation parameter and time to extubation, the sample size was calculated to achieve a sample correlation coefficient of 0.5. It was estimated that at least 47 patients are to be studied with 80 percent power and 5 percent probability of type I error, assuming a population correlation coefficient of 0.75. Analysis was two sided.

Sample size calculation was done with help of nMaster 2.0 (department of biostatistics, Christian Medical College Vellore) software.

Statistical analysis:- Data was summarized by routine descriptive statistics, namely mean and standard deviation for normally distributed numerical variable, median and interquartile for skewed numerical variable and counts and percentages for categorical variables. Association between numerical variables was quantified by calculating Pearson's Rank correlation coefficient 'R' appropriate, after examing for linear relation through construction of scatter plots. Good correlations were observed, regression equation were build based on the variables to predict extubation time in minutes.

Results and Analysis

Regarding demographic profile of the patients mean±SD of age was (54.64±8.11) years, height (157.67±6.944) cm, weight (157.67±6.944) Kg and male: female ratio was 49:7. (Table-1)

VARIABLES	MEAN±SD	MEDIAN
AGE	54.64±8.114	54
HEIGHT	157.67±6.944	158.8
WEIGHT	57.65±6.461	58
M: F	49:7	
BSA	1.58±0.014	1.60
CBG	100.32±1.39	100.50
HEAMOBLOBIN	13.04±1.568	13.05

Table-1- *Demographic variables of patients, mean, median± SD*

Statistically significant difference in rSO2 on Left and Right sides was assessed using paired t tests. There was no statistically significant difference between rSO2 of left and right side ($p > 0.05$). So instead of considering rSO2 Left and rSO2 Right values separately, their mean values (rSO2 values) were considered for further analysis. (Table-2)

	Mean±SD	p valve
rSO2 Lt-baseline rSO2 Rt-baseline	55.79±7.286 55.64±7.873	0.788
rSO2 Lt- preincision rSO2 Rt- preincision	55.41±9.862 55.77±9.473	0.544
rSO2 Lt-after sternotomy rSO2 Rt- after sternotomy	55.36± 9.640 55.91± 8.635	0.392
rSO2 Lt- LAD graft rSO2 Rt- LAD graft	51.13±11.132 51.39± 11.685	0.666
rSO2 Lt- graft 2 rSO2 Rt- graft 2	48.27±10.522 48.98±10.845	0.253
rSO2 Lt-graft 3 rSO2 Rt- graft 3	48.73± 10.541 48.73± 9.786	0.253
rSO2 Lt- after sternal closure rSO2 Rt- after sternal closure	50.55± 9.643 50.64± 9.046	0.880
rSO2 Lt- ICU rSO2 Rt-ICU	51.63±8.130 52.23±8.155	0.157

Table-2- *rSO2 of left and right side at different time intervals*

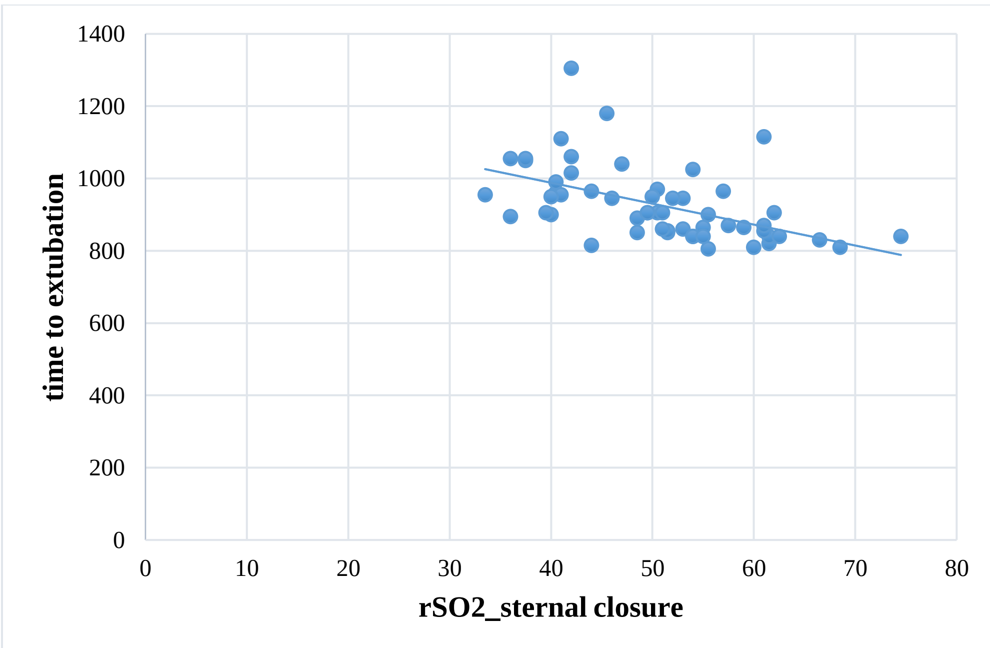

Figure 1: *Scatter plot of time to extubation by regional cerebral oxygen saturation after sternal closure*

The rSO2 values after graft 3, after sternotomy closure and on shifting to ICU shows good correlation with the time taken for extubation (Table-3).

	Time to extubation
rSO2_baseline	-0.29
rSO2_PreIncision	-0.25
rSO2_aftersternotomy	-0.33
rSO2_LAD	-0.48
rSO2_graft 2	-0.46
rSO2_graft 3	-0.58
rSO2_Sternotomy closure	-0.54
rSO2_ICU	-0.56

Table 3:- *Pearson's correlation coefficients for rSO2 with time to extubation*

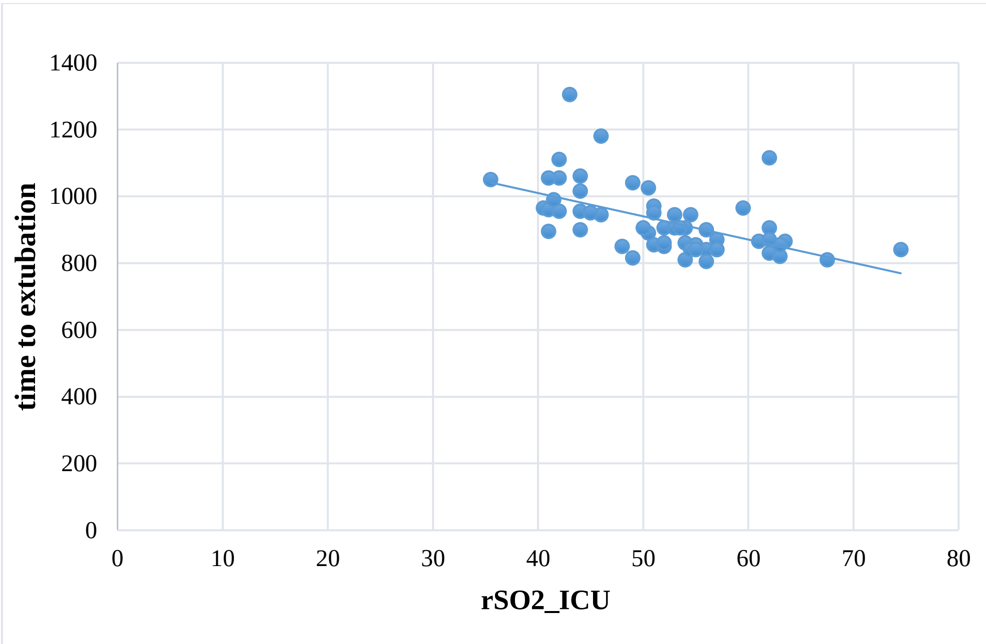

Figure 2: *Scatter plot of time to extubation by regional cerebral oxygen saturation on shifting to ICU*

Significance level was p< 0.0001 after both sternal closure and shifting to ICU with extubation time and 95% confidence interval for time to extubation after sternal closure was -0.6886 to -0.2976 and shifting to ICU was -0.7101 to -0.3354 with rSO2. (Table 4)

Variable Y	Time to extubation
Sample size	56
Variable X	**rSO2_sternal closure**
Correlation coefficient r	-0.5198
Significance level	P<0.0001
95% Confidence interval for r	-0.6886 to -0.2976
Variable X	**rSO2_ICU**
Correlation coefficient r	-0.5498
Significance level	P<0.0001
95% Confidence interval for r	-0.7101 to -0.3354

Table 4: *Significance level and 95% confidence interval for time to extubation by rSO2 after sternal closure and shifting to ICU*

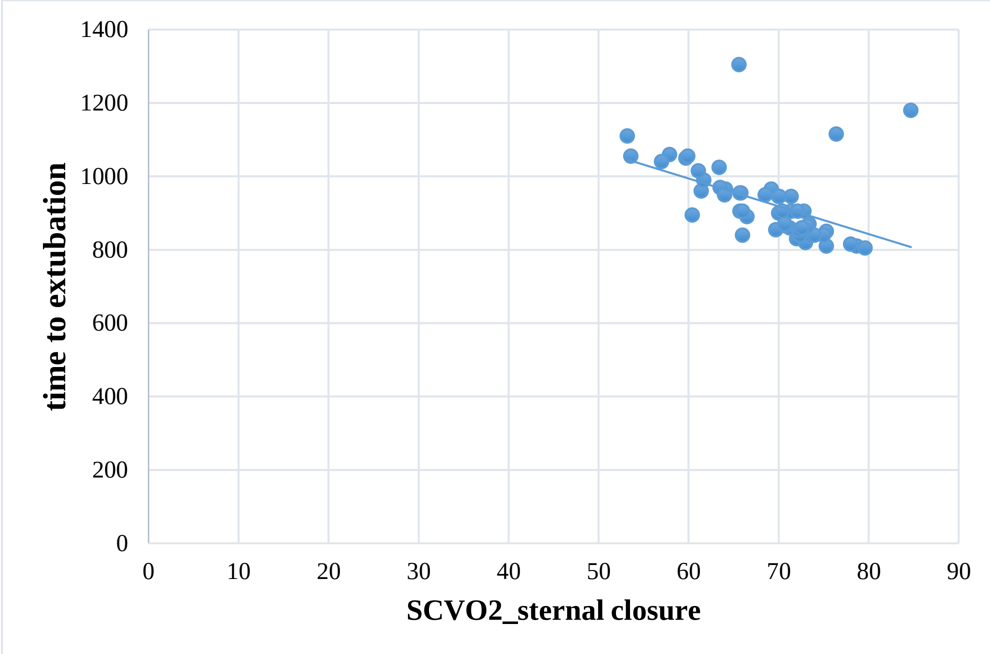

Figure 3: *Scatter plot of time to extubation by central venous oxygen saturation after sternal closure.*

The ScvO2 values after sternotomy closure and on shifting to ICU shows good correlation with the time taken for extubation by Pearson's correlation coefficients (Table-5).

	Time to extubation
SCVO2_ baseline	-0.47
SCVO2_after sternotomy	-0.47
SCVO2_LAD	-0.35
SCVO2_Graft 2	-0.47
SCVO2_graft 3	-0.45
SCVO2_Sternotomy closure	-0.56
SCVO2_ICU	-0.54

Table 5: *Pearson's correlation coefficients for SCVO2 after sternotomy closure and on shifting to ICU*

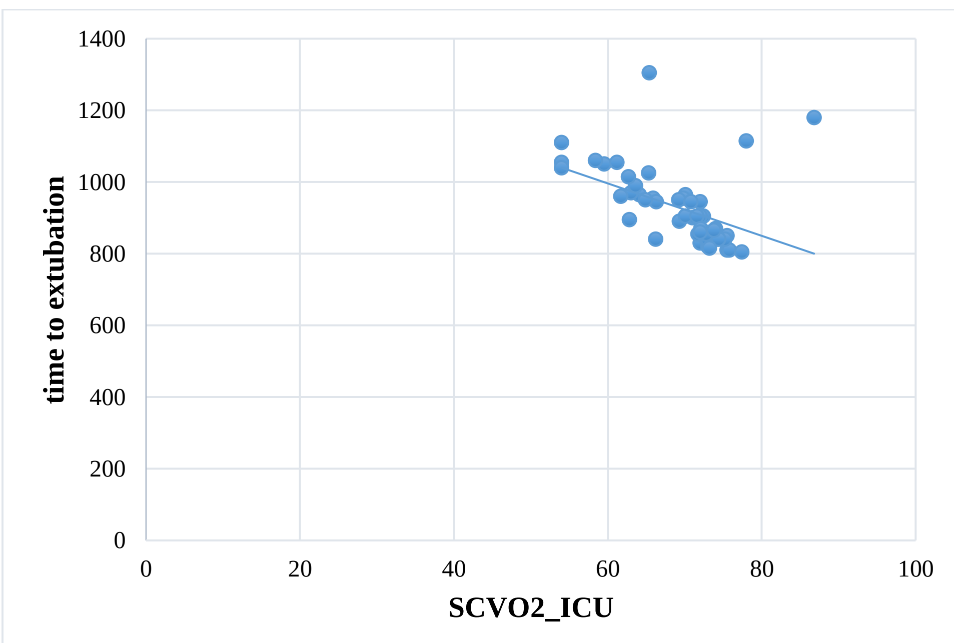

Figure 4: *Scatter plot of time to extubation by central venous oxygen saturation on shifting to ICU.*

The significance level was P=0.0002 after sternal closure and P=0.0004 after shifting to ICU with ScvO2 values and time to extubation while 95% confidence interval for time to extubation by ScvO2 values were -0.6612 to -0.2510 and -0.6431 to -0.2212 after sternal closure and shifting to ICU respectively. (Table-6)

Variable Y	Time to extubation
Sample size	56
Variable X	**SCVO2_Sternal closure**
Correlation coefficient r	-0.4821
Significance level	P=0.0002
95% Confidence interval for r	-0.6612 to -0.2510
Variable X	**SCVO2_ICU**
Correlation coefficient r	-0.4575
Significance level	P=0.0004
95% Confidence interval for r	-0.6431 to -0.2212

Table-6:- *Significance level and 95% confidence interval for time to extubation by SCVO2 after sternal closure and shifting to ICU*

The rSO2 values and the ScvO2 values after sternal closure and on shifting to ICU showed the strongest correlation with time to extubation of the patient.

The other parameters HR, SBP, DBP, MAP, PO2 individually didn't show any correlation with time to extubation.

Discussion

Haemodynamic instability throughout positioning, stabilization and interruption of coronary blood flow are important factors that affect the performance of off-pump CABG[4]. Scientific literature demonstrates that near-infrared spectroscopy (NIRS) monitoring may be able to enhance the detection of hypoxic conditions associated with neurological sequelae and would allow intervention on individual patients and drive refinements in strategies to reduce patients at risk[5].

Shepherd SJ et al states that decrease in ScvO2 is seen in conditions of alveolar hypoventilation, anaemia, heart failure, hypovolemia, pain, agitation, pyrexia, shivering, and respiratory failure whereas oxygen therapy, blood transfusion, intravenous fluids, inotropes, sedation, anaesthesia, analgesia, warming, respiratory support brings about an improvement in ScvO2. It concludes that use of venous oxygen saturation as a therapeutic goal for haemodynamic therapy may reduce postoperative complication rates[6].

Predictors of cerebral oxygen saturation included, partial pressure of carbon dioxide (pCO2), pump flow rate, temperature, mean arterial pressure, haematocrit, heart rate, oxygen saturation(SpO2) [7].

The current study showed that both these oxygenation parameters have strong correlation with the time to extubation of the patient especially after sternal closure and on shifting to ICU. The values of the variables at these time periods bore better correlation with the prognosis of patient suggesting they can be used as surrogate measures of each other, and a correlation may exist between them. Factors influencing the cerebral physiology and these two oxygenation parameters is varied. So interventions to keep it within physiological limit has to be individualized.

Normal rSO_2 values, prior to the induction of GA, range from 60% to 80%. Although lower values (55-60%) for cardiac surgery patients breathing room air are not considered atypical[8]. Besides cerebral oxygenation, baseline cerebral oximetry values reflect a patient's overall cardiopulmonary function and systemic oxygen needs. Cerebral oximetry values were found low in patients with normotensive acute heart failure. Successful treatment increased rSO_2 values[8].

Mixed venous oxygen saturation (SvO2) and central venous oxygen saturation (ScvO2) monitoring has shown mixed results from different randomized controlled trials and meta-analyses. In sepsis, ScvO2 less than 70% or SvO2 lower than 65% correlate with poor prognosis. Certain studies have shown that maintaining goal ScvO2 greater than 70% leads to reduced mortality. Therefore, ScvO2 is used to guide treatment algorithms in the Surviving Sepsis Campaign (SSC). As part of initial resuscitation practice guidelines, SSC recommends achieving a ScvO2 of over 70% within the first 6 hours.[9]

Some authors evaluated the connection between $SvcO_2$ and prognosis and considering $SvcO_2$ optimization as a goal for resuscitation. A decrease in $ScvO_2$ during the first 8 postoperative hours in patients with major surgery was associated with an increase in 28-day morbidity and mortality. In major abdominal surgery $ScvO_2$ <70% was associated with postoperative complications. $ScvO_2$ seems to be a reliable and sensitive parameter to detect hemorrhage in trauma patients. Some suggest that $ScvO_2$ could be a prognosis marker in myocardial infarction acute heart failure and severe sepsis patients.[10]

Nebout S et al concluded ScvO2 maesurement is an interesting tool, especially in the early stages of shock to guide fluid management and blood transfusion and inotropic support[10]. Van Beest P et al concluded that low venous oxygen saturation are important signs for inadequacy to meet oxygen demands. Low values may warn the clinician about cardio-circulatory or metabolic impairment and should urge for further diagnostics and appropriate action, whereas normal or high valve do not rule out persistent tissue hypoxia[11].

Paarmann H et al concluded that rSO2 assessment prior to cardiac surgeries is significantly related to time to extubation , and may thus be used to stratify candidates in fast track programmes[3].

In the current study the rSO2 values towards the end of surgery bore greater significance in terms of extubation of patient. In the current study fast track cardiac anaesthesia was not practised as per Institutional protocol. Schreen T.W. et al states that NIRS offers non invasive online monitoring of tissue oxygenation in a wide range of clinical scenerios. A common application is to measure rSO2 during cardiac surgeries[12].

Moritz S et al concluded, positioning of the heart during off-pump coronary artery bypass grafting leads to a decrease in regional cerebral oxygen saturation. This decrease is associated with changes in cardiac output, haemoglobin concentration, arterial CO2 partial pressure, and central venous pressure[13]. de Tournay-Jetté E et al showed, intraoperative cerebral oxygen desaturation is associated with early and late Post operative Cognitive Dysfunction in elderly patients. Cerebral oximetry is a promising tool in the prediction of subtle neuropsychistric drficits and further studies is needed[14].

Harilall Y et al in another study showed the correlation between central venous saturation and cerebral saturation in the study and indicated that central venous saturation can be used as a surrogate measure of cerebral oxygen saturation, for neurologically asymptomatic patients undergoing OPCAB. The study further stated that with every one unit increase in left cerebral oxygen saturation, there was a corresponding 0.760 unit increase in central venous oxygen saturation and with every one unit increase in right cerebral oxygen saturation, there was a corresponding 0.879 unit increase in central venous oxygen saturation[15].

McQuillen PS et al study on the association between regional and central venous oxygen saturation in paediatric cardiac surgery concluded that neither individual values, nor changes in rSO2 are interchangeable measures of ScvO2 in postoperative paediatric cardiac patients[16].

Coronary artery disease is a disease of the adult population, and cardiac surgery in paediatric population was not considered in the current study. The mean age in the current study population was 54.64±8.114.

Kakuta N et al in a case report noted that ScvO2 shows more marked changes than rSO2, a combination of these two parameters for monitoring during Glenn shunt may be safer[17].

In this study, it has been seen that ScvO2 and rSO2 can both or either be used depending on the economic constrains, to guide therapy during OPCABG. rSO2 by NIRS is a noninvasive method, but it requires new equipments and disposable sensors which may not be economical in many centers. Again, it has the risk of interference from dirt, skin pigmentation, disconnection leading to false readings. ScvO2 is attractive as is readily measurable without any additional monitoring technology. Central venous line is routinely placed in every patient undergoing OPCABG. Even if continuous ScvO2 monitoring by a spectrophotometer is not done, intermittent evaluation after significant events can be equally useful.

The limitations of the study are, small sample size. Events in the ICU factors were not documented which might have influenced the extubation time. Continuous monitoring of ScvO2 with spectrophotometer was not done, while rso2 was continuously monitored by NIRS.

Conclusion

ScvO2 and rSO2 can both can be used to guide therapy. As they are the cumulative effects of many interplaying factors, hence are better predictors than other individual haemodynamic factors. Choosing between any of the two modalities will depend on individualization for the undergoing procedure, patient and institutional infrastructure.

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