DOI: 10.14260/jemds/2015/1640

ORIGINAL ARTICLE

COMPARATIVE EVALUATION OF CENTRAL VENOUS VERSUS ARTERIAL BLOOD SAMPLE FOR REPETITIVE MEASUREMENTS IN CRITICALLY ILL PATIENTS ADMITTED IN INTENSIVE CARE UNIT

Rukhsana Najeeb[1], Nisha Yadav[2], Abraq Asma[3], Mohamad Ommid[4], Farhana Bashir[5], Aamil Hameem[6], Nusrat Jehan[7], Mubasher Ahmad[8]

HOW TO CITE THIS ARTICLE:
Rukhsana Najeeb, Nisha Yadav, Abraq Asma, Mohamad Ommid, Farhana Bashir, Aamil Hameem, Nusrat Jehan, Mubasher Ahmad. "Comparative Evaluation of Central Venous Versus Arterial Blood Sample for Repetitive Measurements in Critically Ill Patients Admitted in Intensive Care Unit". Journal of Evolution of Medical and Dental Sciences 2015; Vol. 4, Issue 65, August 13; Page: 11375-11386, DOI: 10.14260/jemds/2015/1640

ABSTRACT: OBJECTIVES: The purpose of present study was to evaluate the reliability of central venous blood gas monitoring as an alternative to arterial blood gas monitoring and to assess that the central venous catheter is convenient and reliable source of blood for repetitive measurement of pH bicarbonate and PCO2 in critically ill patients admitted in surgical intensive care unit (SICU). **METHODS:** We took one hundred patients who required ABG analysis between 20-60 years of age. The cases were divided in four groups which constituted major admissions in SICU in one year. Out of one hundred patients for the study there were 19 Poisoning patients, 15 Trauma patients, 40 Major abdominal surgery patients, 26 Hypovolemic shock patients and others. Central Venous blood drawn within 5 min of an ABG measurement and the samples analyzed immediately on automated ABG analyzer were compared. **RESULTS:** Bland Altman plots demonstrated a high degree of agreement between the two corresponding sets of measurements of arterial and venous blood with coefficient of correlation 0.979 for pH. The coefficient of correlation was highly positive i.e. 0.926 for PCO_2 and 0.955 for HCO_3^- which is statistically significant. There was also positive correlation for saturation between arterial and venous blood i.e. 0.57 with clinically acceptable difference and is statistically significant. The difference in pO_2 measurements was however higher with correlation coefficient of 0.259 although the arterial saturation and finger oximetry reveals a good degree of agreement with clinically acceptable bias. **CONCLUSION:** Venous blood gas (VBG) analysis clearly does not replace ABG analysis in determining exact pO_2 status and arterial puncture may still be required for invasive arterial BP monitoring. With positive correlation and regression plots obtained, venous samples can be used as an alternative to arterial samples depending on the significant positive correlation values obtained for each parameter separately. Given the well accepted accuracy of pulse oximetry, VBG analysis may be a safer alternative to ABG analysis for determining acid-base status.

KEYWORDS: Arterial blood gas, Venous blood gas, pH, critical care, Ventilator

INTRODUCTION: An intensive care unit or ICU is a specialized section of a hospital that provides comprehensive and continuous care for patients who are critically ill and who can benefit from treatment. Critically ill patients are defined as those patients who are at high risk for actual or potential life-threatening health problems.[1] Thus in a critical ill patient the clinician is more concerned about the ventilation, circulation and metabolism. The disorders of acid-base balance can be found in as many as nine out of every 10 patients in intensive care unit.[2]

The analysis of arterial blood gases (ABG) plays a pivotal role in making correct diagnosis and deciding management strategies in critically ill patients.

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The arterial blood gas analysis is one of the most important investigation for assessment of clinical oxygenation and acid-base status in critically ill patients.[3] It provides us with information about ventilation, oxygenation and acid–base status, the three closely interrelated physiological parameters, which maintain the pH homeostasis. The body is an active chemical reaction requiring a precise balance of acids and bases a measurement known as pH.[4]

The two main organs regulating the acid-base balance are lungs and kidneys. Looking at the gases that are measured it is easy to see how the lung is involved, bringing in oxygen and expelling carbon dioxide. This is known as respiratory metabolism. The kidney is important in metabolic control by actively regulating the dissolved CO_2 or bicarbonate which is in the plasma and is expelled through urine. The common parameters included in arterial blood gas analysis.[5,6] are: pH, PCO_2, PO_2, HCO_3, Hb. and Saturation.

Its correct interpretation and application necessitates the knowledge of basic applied physiology in relation to these parameters. This role can be well exemplified by considering the concept of respiratory failure.[7]

ABG is the only investigation, which can document, specify and quantitate the respiratory failure. High PaCO2, moderately low PaO2 and acidic pH indicate ventilatory failure and low PaCO2, low PaO2 and alkaline pH indicate primary oxygenation failure. The management plan will be ventilatory support in the former case and oxygen therapy in the latter case. Since ABG provides a rapid and accurate assessment of oxygenation, ventilation and acid-base status, the prerequisite for understanding and correctly interpreting ABG is knowledge of basic physiology in relation to ventilation, oxygenation and acid base status.[8]

Through this review an attempt has been made to formulate a comprehensive approach by first describing the basic physiology in relation to ABG, followed by stepwise approach to analyse ABG.

Overall, arterial line placement is considered a safe procedure with a rate of major complications less than 1%.[9] Arterial lines can be placed in multiple arteries, including the radial, ulnar, brachial, axillary, dorasalis pedis, posterior tibial and femoral. The most common site of cannulation is the radial artery, followed by the femoral artery.[10] the radial artery is the site of choice by many due to its ease of cannulation, consistent anatomy, and low rate of complications.[11] the femoral artery has the advantage of having a low risk of thrombosis, but overall a similar rate of complications.

Arterial blood gas (ABG) sampling is widely considered to be essential in the initial diagnostic evaluation of critically ill patients. ABG sampling is invasive, can be difficult but has an important role in the assessment of patients with severe respiratory and metabolic disease, in particular for accurate determination of pH.

Central Venous catheter has become an integral part in the management of critically ill patients being used for fluid administration, an important source of blood sample for chemical analysis and sampling, parenteral nutrition and central venous pressure determination and administration of drugs with high osmolality that cannot be given through peripheral veins and also provides a readily available and safe alternative to repetitive arterial blood gas analysis.[12] The traditional approach, which concentrates on arterial blood gas analysis only, may miss important aspects of oxygen delivery to tissues, especially in patients with poor perfusion.[13]

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Assessing both the arterial blood and central venous samples should result in more efficient and higher quality care for critically ill patients. Although information about arterial blood gases is needed to assess pulmonary gas exchange, in presence of severe hypoperfusion, the hypercapnia and academia at the level of tissues are detected better in central venous blood.[14] Venous blood gas (VBG) analysis clearly does not replace ABG analysis in determining exact Po_2 status, and arterial puncture may still be required for invasive arterial BP monitoring, but given the well-accepted accuracy of pulse oximetry, VBG analysis may be a safer alternative to ABG analysis for determining acid-base status, reducing the need for frequent invasive arterial sampling.[15]

A few authors have expressed doubts the use of VBG values in lieu of arterial values. The aim of this study is to investigate the agreement between ABG and Central VBG samples for all commonly used parameters (pH, Pco_2, Hb% saturation and bicarbonate) in a pathologically diverse ICU patient population.

AIMS AND OBJECTIVES: To evaluate the reliability of central venous blood gas monitoring as an alternative to arterial blood gas monitoring & to assess that the central venous catheter is convenient and reliable source of blood for repetitive measurement of pH, bicarbonate and PCO_2 in critically ill patients.

MATERIALS AND METHODS: After approval by institutional ethical committee and written informed consent from the attendants of patient on mechanical ventilation, this prospective study was conducted in the department of Anesthesiology and Critical Care at Government. Medical College, Srinagar. The study included 100 patients of either gender admitted in surgical intensive care unit between year 2012-2013 needing close monitoring and care in an effort to correct metabolic and respiratory derangements.

A critical ill patient is one at imminent risk of death, the severity of illness must be recognized early and appropriate measures taken promptly to assess, diagnose and manage the illness. Exclusion included patients with cardiac arrest or heart failure.

The Cases were divided in Four Groups which Constituted Major Admission in SICU of Shri Maharaja Hari Singh Hospital Srinagar:

Group I: Poisoning patients.
Group II: Trauma patients.
Group III: Major abdominal surgery patients.
Group IV: Hypovolemic shock patients and others.

All of these patients on mechanical ventilator support with different modes of ventilation with different fractional percentage of oxygen were closely observed and monitored for respiratory, cardiovascular, central nervous system, acid base balance and a complete investigation profile. Under all aseptic precautions arterial line was secured in these patients with 20-22g cannula either in the dorsalis pedis or radial artery, after ruling out any contraindication like bleeding, diathesis. Central venous cannulation was done into either the internal jugular, subclavian, basilica or cephalic vein with either a 16cm long 7Fr double or triple lumen polyurethane catheter or cavafix respectively accordingly to the technique described by Seldinger.

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Proper placement of the catheter was confirmed by determining the observed length of catheter, insertion free respiratory excursion of the column of saline used for measuring CVP aspiration of blood and plain chest radiograph. After the insertion of central venous catheter, a sample of 5ml of blood was obtained from the distal port of the catheter in a 2 or 5ml syringe containing 1-2ml of heparinised saline after securing other ports to avoid dilution of obtained blood sample with infusion fluid or intravenous drug infusion. Alteration in lab results with a heparinised syringe 1-2ml of blood was collected from central line after reattaching the syringe to the CVP catheter and lowering the syringe below the level of CVP line which allowed the blood from the central line to flow into the syringe by its own pressure and eliminated any possibility of trapping of air bubbles.

After collecting the blood sample, the line was flushed with same blood containing heparinised saline syringe to avoid clot formation and line blockade. At the same time 1-5ml of arterial blood was collected in heparinised syringe and repeating the same steps to avoid line blockade. The arterial and venous samples were sent for blood gas analysis. The sampling parameters included in the study were: Ph, PCO_2, PO_2, HCO_2, Hb saturation the collected sample was stored on ice and sent for analysis without any delay. The analysis was done with GEM Premier 3000 analyser within 5mins of collection of blood samples.

PRINCIPLE OF PROCEDURE: THE GEM Premier 3000 analyser is a portable critical care system for rapid analysis of whole blood samples at the point of care. The instrument provides quantitative measurements of pH, blood gases, sodium, potassium, ionized calcium and hematocrit. The analyser uses potentiometric sensors to measure pCO_2, pH, NA^+, K^+, Ca^{++} and amperometric sensors to measure pO_2 concentrations. Blood conductivity is used to measure hematocrit.

STATISTICAL ANALYSIS: The whole data was assimilated in the form of a master chart. The demographical data was analysed by using student 't' test and ANOVA whereas Pearson correlation and Bland Altman plots were used for analyzing the results obtained for comparison of central venous and arterial blood gases. The power of study was 90% with 95% confidence limit. The analysis of the data was performed by using SPSS computer program (Statistical Package for Social Sciences, SPSS Inc. Chicago, USA) version 20.0 and Medcalc.

OBSERVATIONS & RESULTS: Demographic features of overall cases were as follows: Maximum age of patients 60 years, Minimum age of patients 20 years, The mean age of patients 43.12$\pm$13.37, The median age=45

Diagnosis	No. of Cases	Mean	SD	P-value	Remarks
I	19	38.47	12.213		
II	15	39.2	15.086		
III	40	45.77	12.694	0.138	Not sig.
IV	26	44.77	13.498		
Total	**100**	**43.12**	**13.368**		

Table 1: Distribution of age (years) in different diagnosis

There was insignificant difference in the distribution of age in years between the four groups.

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Diagnosis	Male		Female		Total No. of cases
	Count	% age	Count	% age	
I	7	36.80%	12	63.20%	19
II	12	80.00%	3	20.00%	15
III	12	30.00%	28	70.00%	40
IV	11	42.30%	15	57.70%	26
Total	42	42.00%	58	58.00%	100
X^2 =11.465		D.F. = 3			P–value = 0.009

Table 2: Distribution of sex in different diagnosis

There was a significant difference (p=0.015) in distribution of sex in four groups

There were overall 42 males and 58 females:

In group I: There were 7 males and 12 females

In group II: There were 12 males and 3 females

In group III: There were 12 males and 28 females

In group IV: There were 11 males and 15 females.

Diagnosis	No. of Cases	Mean	SD	P-value	Remarks
I	19	51.05	11.616		
II	15	56.00	14.041	0.252	Not sig.
III	40	50.75	9.971		
IV	26	56.54	11.763		

Table 3: Comparison of FiO2 in different diagnosis

Statistically there was insignificant difference in FiO_2 among all groups.

Diagnosis	No. of Cases	Mean	SD	P-value	Remarks
I	19	565.79	47.295		
II	15	576.67	59.362	0.747	Not sig.
III	40	572.5	45.22		
IV	26	561.54	51.59		

Table 4: Comparison of tidal volume in different diagnosis

Statistically there was insignificant difference in VT among all groups (p- value = 0.747)

Diagnosis	No. of Cases	Mean	SD	P-value	Remarks
I	19	11.63	1.739		
II	15	12.73	3.515	0.852	Not Sig.
III	40	12.38	3.801		
IV	26	12.58	5.777		

Table 5: Comparison of respiratory rate in different diagnosis

There was insignificant difference in respiratory rate among the four groups (p-value 0.852).

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Mode 1 – Volume control mode and Mode II – Pressure control mode.

Group	Mode 1	% age	Mode II	% age	Total
I	13	68.40%	6	31.60%	19
II	5	33.30%	10	66.70%	15
III	33	82.50%	7	17.50%	40
IV	20	76.90%	6	23.10%	26
Total	**71**	**71.00%**	**29**	**29.00%**	**1000**
Chi-square = 13.410		d.f. = 3		p.value = 0.004	

Table 6: Comparison of mode in over all cases

Statistically there was highly significant difference in the distribution of ventillatory mode in each group.

Study	N	Mean	SD	Range	Co-efficient of Correlation	P-value	Remark
Method I	100	7.39	0.11	6.794-7.562	0.979	<0.001	HS
Method II	100	7.35	0.11	6.787-7.511			

Table 7: Comparison of pH in method 1 (Arterial) and method II (Venous)

There is high degree of positive correlation 0.979 between pH of arterial and pH of venous and is statistically significant.

Study	N	Mean	SD	Range	Co-efficient of Correlation	P-value	Remarks
Method I	100	35.53	9.08	19.8 – 66.0	0.926	<0.001	HS
Method II	100	41.12	9.67	25.1 – 69.8			

Table 8: Comparison of PaCO2 in method 1 (Arterial) and method II (Venous)

There is high degree of positive correlation of 0.926 in PCO_2 between arterial and venous samples and is statistically significant.

Study	N	Mean	SD	Range	Co-efficient of Correlation	P-value	Remarks
Method I	100	117	49.6	46.9-370.2	0.259	<0.001	HS
Method II	100	45.4	10.4	19.4-91.7			

Table 9: Comparison of pO2 in method 1 (Arterial) and method II (Venous)

There is positive correlation of 0.259 in PO_2 between arterial and venous samples and is statistically significant.

Study	N	Mean	SD	Range	Co-efficient of Correlation	P-value	Remarks
Method I	100	21.11	4.97	6.2–33.8	0.955	<0.001	HS
Method II	100	22.71	5.12	6.8–34.4			

Table 10: Comparison of HCO3 in method 1 (Arterial) and method II (Venous)

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There is high degree of positive correlation of 0.955 in HCO_3 for arterial and venous samples and is statistically significant.

Study	N	Mean	SD	Range	Co-efficient of Correlation	P-value	Remarks
Method I	100	96.77	3.85	74.0–99.8	9.57	<0.001	HS
Method II	100	76.9	10.3	46.0–96.8			

Table 11: Comparison of SpO_2 in method 1 (Arterial) and method II (Venous)

DISCUSSION: This study was carried out in the Postgraduate Department of Anesthesiology and Critical Care Medicine, Government Medical College and associated hospitals Srinagar over a period of one year (2012-2013).

One hundred patients were selected for the study including:

Group 1: Poisoning patients–19.

Group II: Trauma patients–15.

Group III: Major abdominal surgery patients–40.

Group IV: Hypovolemic shock patients and others–26.

Aim of the study was to evaluate the comparison of venous and arterial blood gas values and to evaluate the role of central venous blood gas analysis as an alternative to arterial blood gas analysis. Central venous catheter has an important role in the management of critically ill patients being used in measurement of Central venous pressure, administration of drugs and IV fluids and forms a part of usual protocol in the management of critically ill patients. Role of central venous blood gas analysis began to be identified in early 60's when many workers expressed their experience with the assessment of central venous blood gas values in different sets of patients but only a few had compared it with arterial blood gas values and attempted to draw an agreement between the two methods.

The possibility of using central venous blood rather than arterial blood for acid base analysis has been investigated by many researchers and has been a matter of considerable discussion with difference in opinion for various parameters obtained.

The studies of Weil.[16] and Zahn.[6] concluded that central venous blood mirrors the arterial blood pH and PCO_2 values but did not agree upon the reliability with which the central venous blood may be used for analysis whereas the study of Sutton.[17] and co-workers suggested that the central venous blood gas analysis is reliable as a screening procedure only.

The study of Barrie Phillips.[18] concluded that central venous blood is a reliable and practical substitute to arterial blood gas analysis. Even our study observed highly significant correlation between arterial and central venous pH with a correlation coefficient of 0.979. Similarly there was a highly significant correlation between arterial and venous PCO_2 with a correlation coefficient of 0.926.

Some workers have observed that pH values of the two samples correlate better is non-cardiac arrest than in patients with cardiorespiratory arrest. A possible explanation for this can be that in arrested patients there is a complete loss of cardiac and respiratory function thus the pH of blood signifies the difference between severe metabolic acidosis produced by the tissues and the

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buffering action of blood. The buffering action of lungs and kidneys does not play a role since its acid excreting rate is very slow and this may also be lost because of hypoperfusion.

The varying degree of loss of lung function and of alkali reserve in arrested patient's results in arterial to central venous correlation unlike in non-arrested patients.

The findings of our study are similar to observations made by other workers as well the results of which has been highlighted and compared with present study. Brasheer.[19] conducted a study to devise a relationship between arterial and venous HCO_3^- values. The correlation between arterial and venous HCO_3^- was significant. They presented various equations for predicting arterial HCO_3^-. The study concluded that venous CO_2 has little direct use but when venous CO_2 is abnormal arterial ABG should be obtained.

Steinberg JJ.[20] et al also conducted a study to determine the reliability of central venous blood pH and PCO_2 utilizing regression equation and correlation coefficient methods. Thus study concluded that central venous blood gas analysis would be safe and suitable alternative and more than adequately described the acid base status of the patients. This study included only forty five patients with cardiothoracic procedures.

Parameters	Present study	J. J. Steinberg
pH a –pH cv	0.979	0.882
PCO2A-PCO2V	0.926	0.798

Parameters	J. J. Steinberg	Present Study
pHa range	7.29-7.59	6.794-7.562
pHv range	7.24-7.48	6.787-7.511
(r)	0.6443	0.979
$PaCO_2$ range	20.7 – 46.1	19.8 – 66.0
$pvCO_2$ range	30.0-46.1	25.1-69.8
(r)	0.539	0.926

(r) = correlation coefficient

The observations of Adrogue.[14] quite closely match our observations. He concluded that both arterial and central venous blood samples are needed to assess acid base status in patients with hemodynamic compromise, the hypercapnia and academia at the tissue level are detected better in central venous blood.

The prospective study carried out by Batra Y.K.[21] on patients with various abdominal surgical conditions closely match our observations in evaluating the role of central venous blood gas sampling as an alternative to arterial blood gas sampling.

Our observation as well as our scatter diagram shows a low correlation for PO_2 but a high correlation for pH, PCO_2 and HCO_3^- as shown by study of Batra Y.K.

Richard Treger.[15] et al. also did a prospective study to assess the agreement between arterial and central VBG measurements in medical ICU.

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Parameters	Present Study	Richard Treger's
pHa-pHcv	0.979	0.945
PCO2A-pco2v	0.926	0.883
Hco3A-HCO3 cv	0.955	0.950

There was great similarity in correlation coefficients for pH,PCO_2 HCO_3 in our study and study done by Richard Treger.[15] Thus a number of studies have suggested agreement between AVG and VBG values, although most of the previous studies were limited by specific patient group samples (e.g. patients with diabetic ketoacidosis) or analysis of only one or some parameters rather than all commonly used parameters (e.g. pH,PCo2 and bicarbonate) A few authors even expressed doubts about the use of VBG values in lieu of arterial values. The aim of this study was to investigate the agreement between ABG and central VBG samples for all commonly used parameters (pH, Pco2 PO2 Hb, saturation and bicarbonate) in a pathologically diverse ICU patient population.

SUMMARY AND CONCLUSION: The purpose of present study was to evaluate the reliability of central venous blood gas monitoring as an alternative to arterial blood gas monitoring and the assess that the central venous catheter is convenient and reliable source of blood for repetitive measurement of pH bicarbonate and PCO2 in critically ill patients admitted in surgical intensive care unit (SICU).

We took one hundred patients who required ABG analysis between 20-60 years of age. The cases were divided in four groups which constituted major admissions in SICU in one year.

Out of one hundred patients for the study there were 19 Poisoning patients, 15 Trauma patients, 40 Major abdominal surgery patients, 26 Hypovolemic shock patients and others. The mean age of patients was 43.12$\pm$13.37 yrs. The median age of patients was 45. There was over all 42 males and 58 females

There was statistically insignificant difference in age, respiratory rate, tidal volume among all groups, though there was significant difference in distribution of age and various modes of ventilation.

Central Venous Blood Drawn within 5 min of an ABG Measurement and the Samples Analyzed Immediately on Automated ABG Analyzer were Compared:

1. Bland Altman plots demonstrated a high degree of agreement between the two corresponding sets of measurements of arterial and venous blood with coefficient of correlation 0.979 for pH.
2. The coefficient of correlation was highly positive i.e.; 0.926 for PCO_2 which is statistically significant.
3. The coefficient of correlation was highly positive i.e.; 0.955 for HCO_3^- which is statistically significant.
4. There was also positive correlation for saturation between arterial and venous blood i.e. 0.57 with clinically acceptable difference and is statistically significant.
5. The difference in pO_2 measurements was however higher with correlation coefficient of 0.259 although the arterial saturation and finger oximetry reveals a good degree of agreement with clinically acceptable bias.

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CONCLUSION:

1. Venous blood gas (VBG) analysis clearly does not replace ABG analysis in determining exact pO_2 status and arterial puncture may still be required for invasive arterial BP monitoring.
2. Although the difference in the blood gas parameters obtained from arterial and venous samples was statistically significant but with positive correlation and regression plots obtained, venous samples can be used as an alternative to arterial samples depending on the significant positive correlation values obtained for each parameter separately.
3. Given the well accepted accuracy of pulse oximetry, VBG analysis may be a safer alternative to ABG analysis for determining acid-base status, reducing the need for frequent invasive arterial sampling thus avoiding time consuming and complicated procedure of arterial cannulation in patients requiring prolonged mechanical ventilation in surgical Intensive Care Unit.

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DOI: 10.14260/jemds/2015/1640

ORIGINAL ARTICLE

AUTHORS:

1. Rukhsana Najeeb
2. Nisha Yadav
3. Abraq Asma
4. Mohamad Ommid
5. Farhana Bashir
6. Aamil Hameem
7. Nusrat Jehan
8. Mubasher Ahmad

PARTICULARS OF CONTRIBUTORS:

1. Professor, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
2. Resident, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
3. Lecturer, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
4. Assistant Professor, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
5. Senior Resident, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
6. Senior Resident, Department of Anaesthesiology and Critical Care, Lady Hardinge Medical College, Delhi.
7. Assistant Professor, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.
8. Lecturer, Department of Anaesthesiology and Critical Care, Government Medical College, Srinagar.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Rukhsana Najeeb,
Professor,
Department of Anaesthesiology
and Critical Care,
Post Box: 659, GPO,
Srinagar-190001, Jammu and Kashmir.
E-mail: ommid76@yahoo.com

FINANCIAL OR OTHER COMPETING INTERESTS: None

Date of Submission: 23/07/2015.
Date of Peer Review: 24/07/2015.
Date of Acceptance: 05/08/2015.
Date of Publishing: 12/08/2015.