Archives of Anesthesiology and Critical Care (Spring 2023); 9(2): 132-137.

Available online at http://aacc.tums.ac.ir

Research Article

Comparison of Pre-Oxygenation with Single Vital Capacity Breath Technique and Tidal Volume Breathing Technique for Adult Patients Undergoing General Anaesthesia

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ARTICLE INFO

Article history:
Received 10 May 2022
Revised 29 May 2022
Accepted 14 Jun 2022

Keywords:
Arterial oxygen;
End tidal oxygen;
Pre-oxygenation;
Single vital capacity breath technique;
Tidal volume breathing technique

ABSTRACT

Background: Pre-oxygenation before induction of general anaesthesia is widely used for enhancing oxygen reserves and preventing hypoxia. Several techniques for pre-oxygenation have been described. This study was designed to compare the PaO2 and ETO2 with single vital capacity breath technique (SVCB) and tidal volume breathing technique (TVB) for adult patients undergoing general anaesthesia.

Methods: Fifty patients were pre-oxygenated with both techniques - first SVCB then TVB separated by five minutes of breathing room air or till ETO2 & PaO2 values reached baseline values (whichever was later). ABG samples & ETO2 readings were taken before pre-oxygenation & every thirty seconds for three minutes in both techniques.

Results: Pre-test, mean PaO2 and ETO2 values of both techniques (SVCB and TVB) were similar. In SVCB technique, the mean PaO2 (mmHg) and ETO2 (%) significantly increased at 30 seconds ($p \leq 0.001$) from 95.26 and 17.14 (pre-test time) to 304.34 and 92.48 respectively. In TVB technique, an exponential increase was noted. The mean PaO2 (mmHg) and ETO2(%) significantly increased at 180 seconds ($p \leq 0.001$) from 96.26 and 16.26 (pre-test time) to 305.64 and 93.08 respectively. Peak values of oxygenation in both groups were similar but achieved at different time points.

Conclusion: SVCB technique achieves high oxygenation rapidly but is not sustained thus can be used for rapid sequence induction though not recommended for difficult airway scenarios. TVB technique also achieves high oxygenation but steadily. TVB may be used for induction, including, rapid sequence induction but after 3-5 minutes of pre-oxygenation.

Pre-oxygenation before induction of general anesthesia is universally used maneuver for prevention of hypoxia by denitrogenation of lungs. It provides more time to secure the airway, especially in situations of anticipated difficult airway and tracheal intubation. Apnea time is defined as the duration taken until the patient reaches a saturation level of 90% [1-3]. During apnea, tissue oxygenation is maintained by consumption of reserve oxygen. Pre-oxygenation with 100% oxygen enhances the safety buffer [1-4]. Many techniques are used to accomplish pre-oxygenation like tidal volume breath over a period of time, deep breathing and single vital capacity breath methods. In this study we compared two techniques - single vital capacity breath technique (SVCB) and tidal volume breathing (TVB) technique, using PaO2 and ETO2 as parameters of oxygenation.

Methods

After the approval of hospital ethics committee, CTRI registration and written informed consent, fifty adult

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patients were enrolled into a comparative, cross - over study in our institute.

The study was carried out on patients aged 18-60 years old, of ASA I and II, of either sex, scheduled for elective surgery under general anaesthesia. Patients with normal pulmonary & cardiac functions with BMI less than 30 kg/m2 only were included in this study.

After complete pre-anaesthetic evaluation, we explained the method of the two techniques of pre-oxygenation, i.e., SVCB (single vital capacity breath technique) and TVB (tidal volume breath technique) to all the patients. All patients were fasted eight hours prior to the surgery.

The patient was shifted in the operation theatre after Dragger Primus anaesthesia station was checked. Standard ASA monitoring's, i.e., heart rate (HR), electrocardiography (ECG), non-invasive blood pressure (NIBP), Oxygen saturation (SpO2), using Canvys multiparameter monitor, model no. ROM1532CM were initiated.

An intravenous access was secured and inj. Midazolam 1mg was given to all patients intravenously. Radial artery was cannulated after local anaesthetic infiltration and a sample of arterial blood gas (first baseline sample) was taken on room air. Arterial blood gas analysis (ABG) was done using pHOx Ultra Nova Biomedical ABG machine.

An adult anaesthesia circuit (circle system with CO2 absorber) was used after priming by flushing the circuit with 100% oxygen at 6 l /min and partially occluding its patient end with hand for one minute, while keeping its two-liter capacity bag fully inflated.

Each patient was pre-oxygenated with both techniques (first SVCB then TVB technique) with five minutes of breathing room air in between the two or till PaO2 and ETO2 values reached baseline which ever was later. Each patient served as his/her own control. The values obtained were labelled into two groups, i.e., SVCB and TVB

Method of SVCB - The patient was asked to take maximal forced expiration. Mask of primed circuit was applied to patient's face achieving leak free seal. The patient was then asked to take a single vital capacity inspiration and hold it for as long as possible. Flow of oxygen was 10 l/min. Recording of ETO2 values and ABG samplings were done. Before starting the testing with second technique, the circuit was primed again.

Method of TVB - Patient was asked to take normal tidal volume breaths for three minutes from a leak free face mask through a closed circuit with 100% oxygen, at a flow of 10 l/min. Recording of ETO2 values and ABG samplings were done.

Arterial blood gas samples and End Tidal Oxygen values (ETO2) were taken before pre-oxygenation (baseline), at every 30 seconds till three minutes with SVCB technique, second baseline sample on room air, then at every 30 seconds till three minutes with TVB technique.

Statistical methods

Methods of pre-oxygenation were studied by Anis Baraka et al. They observed the mean PaO2 values in traditional tidal volume breathing at 30 secs were 192 + 85 mmHg whereas in pre oxygenation with the SVCB technique were 295+67 mmHg. Taking these values as reference, the minimum required sample size with 95% of power of study and 1% level of significance is 10 patients. However, we took 50 patients in each group to reduce margin of error. Systematic sampling was done. Formula for calculation of sample size was:

$$N \geq \frac{(\text{standard deviation})2*(Z+Z)}{(\text{Mean difference})2}$$

Where Z alpha is value of Z at two sided alpha errors of 1% and Z beta is value of Z at power of 95% and mean difference is difference in mean values of two techniques.

Mean and median values were calculated using values (50 in number) of each parameter for each time point in both groups. Range of values in each group at each time point was noted.

To statistically compare the mean and median values at each time point between the two groups (SVCB and TVB), p values were calculated. A p value of <0.05 was considered statistically significant.

The change of oxygenation parameters (PaO2 and ETO2) were compared in the two groups (SVCB and TVB) using Generalized Estimating Equations Method.

Statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0.

Results

The demographic profiles of the two groups were similar. 50 patients (24 males & 26 females) were studied over a period of 1 year. The pre-test mean PaO2 and ETO2 values on room air of both groups (SVCB and TVB) were statistically similar (p>0.05).

The mean PaO2 and ETO2 values were significantly higher ($p \leq 0.001$) at 30 seconds time point (304.34 ±49.36 mmHg and 92.48± 2.44 %) than pre-test values (95.26 ± 8.99mmHg and 17.14 ± 1.94%) respectively, in SVCB group (Table 1-2).

The mean PaO2 and ETO2 values at 30 seconds (163.40 ± 25.69 mmHg and 83.14 ± 10.46 %) in TVB group were not significantly different than respective pre-test values (Table 3-4).

This proves that SVCB pre-oxygenation generates significantly higher peak oxygen values, quickly (i.e., within 30 seconds of start of pre-oxygenation).

The mean PaO2 and ETO2 values steadily fell to near pre-test values in SVCB group at 3 minutes after initial peak at 30 seconds. (Table 1-2 and Figures 1-2).

In TVB group the mean PaO2 and ETO2 values steadily rose all through the test period and reached peak values at 3 minutes. (Table 3-4 and Figures 1-2). These

peak values of TVB group were similar to peak values of SVCB group at 30 seconds. (Table 5-6 and Figures 1-2).

The mean PaO2 and ETO2 values in TVB group were significantly higher than SVCB group at 3 minutes. (Table 5-6 and Figures 1-2).

The overall trend of the oxygenation parameters (i.e., PaO2 and ETO2) showed significant difference within each group (within SVCB or TVB) as well as between the two groups (i.e., SVCB and TVB). In SVCB group the values were significantly high at 30 seconds and continued so till about 2 minutes and in TVB group, these values were significantly high after 1minute and continued till 3 minutes. While comparing the oxygenation parameters between the two groups, both achieved equally high values but at different times i.e., at 30 seconds in SVCB group and at 3 minutes in TVB group.

Table 1- PaO2 in SVCB group

Time	SVCB (PaO2)			P value vs Pre-test
	Mean (SD)	Median (IQR)	Range	
Pre-test	95.26 (8.99)	98.50 (13.75)	78.00-109.00	
30 Seconds	304.34 (49.36)	298.00 (82.00)	232.00-406.00	<0.001 (S)
60 Seconds	216.52 (60.04)	205.00 (103.75)	120.00-355.00	<0.001 (S)
90 Seconds	174.76 (48.13)	173.50 (65.25)	96.00-290.00	<0.001 (S)
120 Seconds	144.26 (39.67)	147.00 (46.50)	83.00-292.00	<0.001 (S)
150 Seconds	125.00 (37.13)	124.50 (42.00)	76.00-295.00	0.003 (S)
180 Seconds	108.52 (23.79)	100.50 (34.75)	75.00-166.00	0.747 (NS)

SVCB: Single vital capacity breath, NS: Not significant, S: Significant

Table 2- ETO_2 in SVCB group

Time	SVCB ETO2 (%)			P value vs pre-test
	Mean (SD)	Median (IQR)	Range	
Pre-test	17.14 (1.94)	17.00 (3.00)	14.00-20.00	
30 Seconds	92.48 (2.44)	93.00 (3.50)	88.00-97.00	<0.001 (S)
60 Seconds	75.40 (11.97)	80.00 (18.50)	50.00-90.00	<0.001 (S)
90 Seconds	58.72 (13.91)	62.00 (24.25)	32.00-86.00	<0.001 (S)
120 Seconds	42.78 (15.24)	45.50 (25.50)	16.00-69.00	<0.001 (S)
150 Seconds	30.46 (11.57)	30.50 (17.50)	15.00-54.00	0.007 (S)
180 Seconds	21.22 (11.29)	20.00 (8.75)	13.00-92.00	0.837 (NS)

SVCB: Single vital capacity breath, NS: Not significant S: Significant

Table 3- PaO2 in TVB group

Time	TVB (PaO2)			P value vs pre-test
	Mean (SD)	Median (IQR)	Range	
Pre-test	96.26 (8.90)	98.50 (13.75)	78.00 - 109.00	
30 Seconds	163.40 (25.69)	159.00 (31.50)	100.00 - 219.00	0.272 (NS)
60 Seconds	214.16 (27.18)	206.50 (34.00)	162.00 - 268.00	<0.001 (S)
90 Seconds	244.74 (30.81)	245.50 (41.00)	172.00 - 296.00	<0.001 (S)
120 Seconds	261.84 (30.80)	266.50 (41.00)	196.00 - 324.00	<0.001 (S)
150 Seconds	274.70 (30.36)	277.50 (41.00)	210.00 - 356.00	<0.001 (S)
180 Seconds	305.64 (48.99)	298.00 (85.50)	230.00 -	<0.001 (S)

	399.00

TVB: Tidal volume breathing, NS: Not significant, S: Significant

Table 4- ETO2 in TVB group

Time	TVB ETO2 (%)			P value vs pre-test
	Mean (SD)	Median (IQR)	Range	
Pre-test	16.26 (1.4)	17.00 (2.00)	14.00-20.00	
30 Seconds	83.14 (10.46)	85.50 (8.00)	17.00-91.00	0.272 (NS)
60 Seconds	88.78 (3.87)	90.00 (5.75)	76.00-95.00	<0.001 (S)
90 Seconds	90.84 (2.41)	91.00 (4.00)	86.00-95.00	<0.001 (S)
120 Seconds	91.80 (2.52)	92.00 (4.00)	86.00-96.00	<0.001 (S)
150 Seconds	92.40 (2.54)	92.00 (5.00)	88.00-96.00	<0.001 (S)
180 Seconds	93.08 (2.69)	93.00 (5.00)	88.00-97.00	<0.001 (S)

TVB: Tidal volume breathing, NS: Not significant, S: Significant

Table 5- Comparison of PaO2(mmHg) in SVCB and TVB groups over time (n = 50)

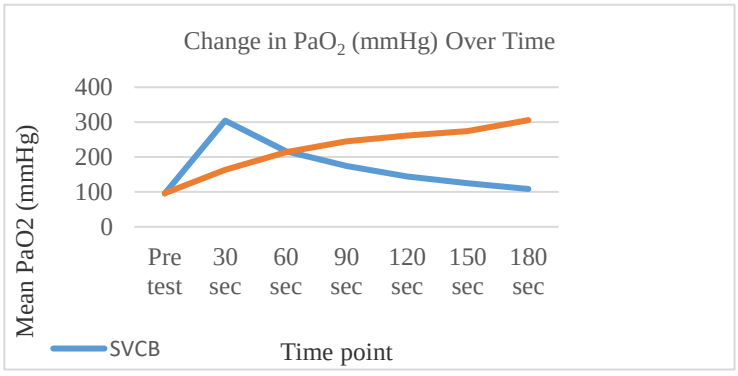
Time	Technique				P value for comparison of the two groups at each time points (Wilcoxon Test)
	SVCB (PaO2)		TVB (PaO2)		
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Pre-test	95.26 (8.99)	98.50 (13.75)	96.26 (8.99)	98.50 (13.75)	0.904 (NS)
30 Seconds	304.34 (49.36)	298.00 (82.00)	163.40 (25.69)	159.00 (31.50)	<0.001 (S)
60 Seconds	216.52 (60.04)	205.00 (103.75)	214.16 (27.18)	206.50 (34.00)	0.908 (NS)
90 Seconds	174.76 (48.13)	173.50 (65.25)	244.74 (30.81)	245.50 (41.00)	<0.001 (S)
120 Seconds	144.26 (39.67)	147.00 (46.50)	261.84 (30.80)	266.50 (41.00)	<0.001 (S)
150 Seconds	125.00 (37.13)	124.50 (42.00)	274.70 (30.36)	277.50 (41.00)	<0.001 (S)
180 Seconds	108.52 (23.79)	100.50 (34.75)	305.64 (48.99)	298.00 (85.50)	<0.001 (S)

SVCB: Single vital capacity breath, TVB: Tidal volume breathing, NS: Not significant, S: Significant

Table 6- Comparison of ETO2(%) in SVCB and TVB groups over time (n= 50)

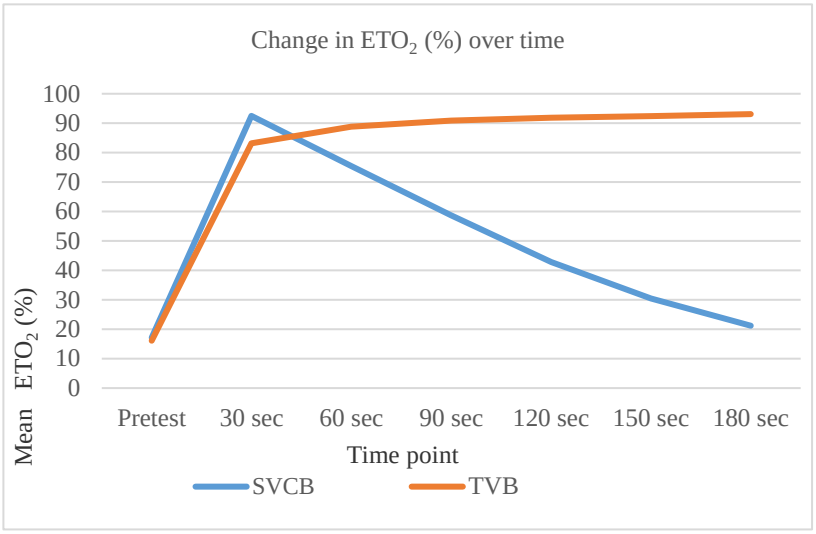
Time	Technique				P value for comparison of the two groups at each of the time points (Wilcoxon Test)
	SVCB ETO2 (%)		TVB ETO2(%)		
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Pre-test	17.14 (1.94)	17.00 (3.00)	16.26 (1.4)	17.00 (2.00)	>0.05 (NS)
30 Seconds	92.48 (2.44)	93.00 (3.50)	83.14 (10.46)	85.50 (8.00)	<0.001 (S)
60 Seconds	75.40 (11.97)	80.00 (18.50)	88.78 (3.87)	90.00 (5.75)	<0.001 (S)
90 Seconds	58.72 (13.91)	62.00 (24.25)	90.84 (2.41)	91.00 (4.00)	<0.001 (S)
120 Seconds	42.78 (15.24)	45.50 (25.50)	91.80 (2.52)	92.00 (4.00)	<0.001 (S)
150 Seconds	30.46 (11.57)	30.50 (17.50)	92.40 (2.54)	92.00 (5.00)	<0.001 (S)
180 Seconds	21.22 (11.29)	20.00 (8.75)	93.08 (2.69)	93.00 (5.00)	<0.001 (S)

SVCB: Single vital capacity breath, TVB: Tidal volume breathing, NS: Not significant, S: Significant



SVCB-Single vital capacity breath, TVB -Tidal volume breathing

Figure 1-The following is line diagram depicting the change in PaO2 (mmHg) over time in both groups



SVCB-Single vital capacity breath, TVB -Tidal volume breathing

Figure 2- The line diagram depicting the change in ETO2 (%) over time in both the groups

Discussion

Pre-oxygenation is a quintessential part of anaesthesia induction whether elective or emergency. The time required for adequate pre oxygenation is directly related to the rate of alveolar denitrogenation. The three factors upon which denitrogenation depends are fraction of inspired oxygen, tidal volume and respiratory frequency. The different variations of these last two factors are the origin of two common pre oxygenation techniques which are slow and fast techniques. Slow technique is the conventional tidal volume breathing technique for approximately 3 minutes [1]. Conventional tidal volume breathing for 2-3 minutes results in 95% denitrogenation [5-6]. By exhaling fully before TVB technique, oxygenation can be further optimized [5-7]. We also used this concept in our methodology. Fast techniques include 4 deep breaths (4 DB) or vital capacity breaths over 30 seconds, 8 deep breaths (8 DB) over 60 seconds [1]. High minute ventilation is the basis of fast pre oxygenation. Anis Baraka et al [7] concluded that 8 DB technique over 60 seconds with 10 l/min oxygen flow resulted in similar PaO2 values as following TVB technique for 3 minutes. Results of our study were similar to Anis Baraka et al [7]. We evaluated the effect of single vital capacity breath technique (fast technique) and tidal volume breathing technique (slow technique) on two oxygenation indices, PaO2 and ETO2 in fifty adult patients. Anis Baraka et al [7] used only PaO2 as a sole marker of pre oxygenation in just ten adult patients. Tanoubi et al [1] also concluded that oxygenation parameters, FEO2 (Fraction of oxygen in expired air) and DAWD (duration of apnea without desaturation) measured at 3 mins after TVB technique is similar to 8 DB over 60 secs. We also noted a significant rise in both PaO2 and ETO2 values at 30 secs with SVCB technique which is comparable with TVB technique at 3 mins. Gold et al [8] compared PaO2 and CaO2 (arterial O2 content) values obtained after 4DB at 30 secs with TVB for 5 mins and found that they were not significantly different. They required longer time (5mins vs 3mins) to reach comparable values as they used lower oxygen flows (5l/min vs 10 l/min) and semi closed circuit while closed circuit was used in our study. Differences in methodology and measured parameters have resulted in varying conclusion in different studies. A common conclusion is achievement of peak PaO2 in 30-60 secs with deep breathing techniques, but which is not sustained. The peak PaO2 values in 30-60 secs is comparable to slow TVB technique at 3 minutes. Pandey et al [3] noted that the apnea period in 100 healthy adults following TVB technique was mean 281.70 seconds which is significantly longer than mean 110 seconds noted in 4 DB technique. This finding is in agreement with our study. In TVB group in our study, the mean PaO2 and ETO2 values steadily rose all through the test period and reached peak values at 3 mins. In SVCB group the values were significantly high at 30 seconds and then they steadily declined to reach pre-test values in 3 mins.

Conclusion

In our study Single vital capacity breath technique achieves high oxygenation rapidly but it is not sustained so it can be used for rapid sequence induction but is not recommended for difficult airway scenarios. Tidal volume breath technique also achieves high oxygenation but steadily. TVB may be used for induction, including,

rapid sequence induction but after 3-5 minutes of pre-oxygenation.

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