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Arterial Oxygen Desaturation Rate following Obstructive Apnea in Parturients

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This study was attempted to observe the rate of oxygen desaturation after full oxygenation in six parturients scheduled for Cesarean sections and six patients scheduled for transabdominal hysterectomies. We calculated the mean rate of fall of arterial saturation (slope of desaturation: $<SaO_2\ (t_2)-SaO_2(t_1)>/t_2-t_1$) and changes in arterial blood gases were observed. All subjects were denitrogenated then a single isolated apnea was carried out. The mean time to obtain 90% saturation was longer in the nonpregnant group (7.5 min vs 3.6 min in parturients). The mean slope of desaturation was steeper in the parturients (−3.34) than the nonpregnant group (−1.52). As far as the oxygen reserve is concerned, the parturients had a lesser margin of safety than the nonpregnant women. It was concluded that the lower the thoracic gas volume (parturients), the lower the alveolar O_2 stores and, the more rapidly these stores are depleted.

Key Words: *Apnea, Parturients. Oxygen reserve, Desaturation*

INTRODUCTION

Preoxygenation is a standard anesthetic technique for preventing significant hypoxemia during the induction of anesthesia. Until recently, anesthetists have thought only in terms of "preoxygenation". Due to the limited information obtained from arterial oxygen saturation or content, a change in focus from "preoxygenation" to the more relevant concept of "denitrogenation" should be made. Because the washout of nitrogen from the lungs is the key to achieve adequate preoxygenation, complete denitrogenation is especially important in clinical situations of difficult intubation or decreased functional residual capacity (pregnancy, ascites, etc), and in situations where the oxygen saturation is critical (Hanilton et al, Gambee et al).

Lung volumes and lung capacities are not greatly changed by pregnancy but changes are primarily limited to the functional residual capacity (Baldwin et al) and the diaphragm is not splinted at term, but moves freely. However, the supine position markedly impairs respiratory function in late pregnancy.

Oxygen consumption in pregnancy is markedly increased at term as compared to the nonpregnant state (Andersen et al). In pregnant women, whose lung volume is also small, PaO_2 may decrease more rapidly during apnea than in nonpregnant women (Archer et al, Wattzener et al) so these factors make the pregnant parturients more vulnerable to hypoxia. This justifies increasing FiO_2 in parturients undergoing general anesthesia. It is important to evaluate how long parturient women can withstand apneic hypoxemia during the induction of general anesthesia. This study was carried out to measure the duration of time required to decrease the SaO_2 down to 90%.

METHODS

After securing institutional review board approval, a written informed consent was obtained from six healthy parturients who were to undergo elective Cesarean sections and six healthy nonpregnant women who were to have transabdominal hysterectomies. The arterial blood gas tension and oxygen saturation were measured.

After the patient was moved to the operating table,

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the radial artery was cannulated with a 22 G Angiocath to obtain arterial blood for gas analysis. After a period of stable tidal breathing of 21% oxygen (room air) to establish a stable respiratory pattern and baseline values for oxygen and carbon dioxide, arterial blood samples were drawn and analysed using a blood gas analyser (Corning 178) and those data were named control data, this was followed by denitrogenation. All subjects had a tight fitting anesthesia mask applied and breathed through the semiclosed circuit system into which 100 per cent oxygen was flowing at 7 liters per minute. A Raman spectroscope (Rascal Albion) continuously measured the nitrogen concentration. When the inspired nitorgen concentration (FiN_2) was reduced to less than 1 per cent and the expired nitrogen concentration (FeN_2) less than 5 per cent, the patient was intubated with a cuffed endotracheal tube using thiopental and succinylcholine. For nonpregnant group supplemental doses of thiopental 1 mg/kg were administered 2 min after the initial dose and then every minute until the completion of the study. Supplemental doses of succinylcholine 0.5 mg/kg were administered 3 min after the initial dose and then every 2 min until the completion of the study. Then a single isolated apnea was induced by inflating the cuff of the endotracheal tube and simultaneously obstructing the connector of the tube. Arterial gases were measured immediately after this time and the term "denitrogenation data" was applied to this data. When the pulse oximeter (Omeda biox 3740) indicated 90% saturation, arterial gas tensions were measured.

From these, the arterial oxygen content was calculated (O_2 content $= Hg \times 1.34 \times SaO_2 + 0.003 \times PaO_2$), and the mean desaturation rate from denitrogenation to the time SaO_2 decreased to 90% was calculated ($dSaO_2/dt$).

The mean values for results at each period were compared using Student's t-test, $p<0.05$ being the criterion for statistical significance.

RESULTS

The characteristics of the two groups are given in table 1. There were no statistically significant differences in age, weight, height, total lung capacity and hemoglobin concentration between two groups. However, hemoglobin concentrations of the parturients were somewhat lower than those of the nonpregnant group. Total lung capacities were calculated using the pulmonary function prediction nomogram introduced by H.G. Boren. The results are shown in table 2.

Before the subjects breathed 100% oxygen, there were no statistically significant differences in mean SaO_2, PaO_2 and oxygen content between the groups. However, there was a tendency for the arterial oxygen content in the non-pregnant group to be higher than the parturients. Such a difference was considered to be due to the low hemoglobin concentration of the parturients. $PaCO_2$ in the parturients was lower than the nonpregnant group. This is a characteristic of pregnant women resulting from maternal hyperventilation. Figure 1 shows the changes in arterial oxygen saturation. The arterial oxygen saturation increased to nearly 100% in all the subjects after denitrogenation.

The mean time to a 90% saturation measured by pulse oximeter was 7.5 ± 0.9 min in the nonpregnant group and 3.6 ± 0.8 min in the parturient group. The times for SaO_2 to decrease to about 90% were variable but significantly shorter in the parturient group than the nonpregnant group.

The mean slope of desaturation was steeper in the parturient group (-3.34) than the nonpregnant group (-1.52).

When blood gases were obtained it was found that one parturient woman was desaturated to near 70% at 3.5 min. In this case, An Apgar score of the newborn baby was 7. Coincidentally we had similar data in one nonpregnant woman. The time to this level of

Table 1. Demographic Data

	Nonpregnant Group (n = 8)	Parturient Group (n = 8)
Age (years)	39.8 ± 11.5	29.3 ± 3.8
Weight (Kg)	51.8 ± 9.7	61 ± 3.2
Height (cm)	156.5 ± 5.5	158 ± 5.3
Total Lung Capacity (L)	4.9 ± 0.4	5.0 ± 0.4
Hemoglobin (gm/dl)	13.6 ± 0.8	12.2 ± 1.5

Values are means $\pm$ SD.
There are no significant differences between the two groups.
Total lung capacities are calculated using the pulmonary function prediction nomogram of H.G. Boren (Am J Med 41:96, 1968).

Table 2. Mean (SD) Gas Values during the Procedure for Two groups: Parturient Group (I), Nonpregnant Group (II)

		Control Data	Denitrogenation	SaO_2 90% by Oximeter	dt (min)	$dSaO_2/dt$
SaO_2 %	Group I	98.0 (1.0)	99.8 (0.1)*	88.6 (8.8)*	3.6 (0.8)°	−3.34
	Group II	97.3 (0.9)	99.9 (0.1)*	88.7 (10.8)	7.5 (0.9)	−1.52
PaO_2 mmHg	Group I	98.2 (4.4)	381.1 (64.3)*	68.5 (15.4)*		
	Group II	99.8 (9.7)	419.3 (32.5)*	77.8 (23.3)*		
CaO_2 ml/dl	Group I	16.9 (2.1)	18.0 (2.1)	15.6 (3.2)		
	Group II	18.4 (0.9)	19.7 (1.4)	16.8 (2.4)*		
$PaCO_2$ mmHg	Group I	32.7 (2.3)°	32.6 (3.0)	56.1 (6.3)*		
	Group II	39.5 (5.5)	39.4 (7.9)	59.7 (11.2)*		

data = mean (SD)
dt : mean time from denitrogenation to SaO_2 90%
$dSaO_2/dt$: the slope of desaturation
* : Significantly different from preceding period. $p<0.05$
° : Significantly different from the nonpregnant group. $p<0.05$

desaturation in the nonpregnant woman was 7.7 min.

Figure 2 shows the changes of PaO_2. This graph shows a similar pattern of change with the SaO_2 graph. The PaO_2 increased over 400 mmHg in both groups after denitrogenation. When oxygen saturation decreased to 90%, the mean PaO_2 of the nonpregnant group and parturients group were 77.8 mmHg, and 68.5 mmHg respectively ($p<0.05$).

Figure 3 shows the changes of the arterial oxygen content. They increased slightly after denitrogenation in both groups. However, there are no significant differences between the control and the denitrogenation data in both groups. It was suggested that the oxygen reserve in the blood did not increase significantly even if patients breathed with 100% oxygen.

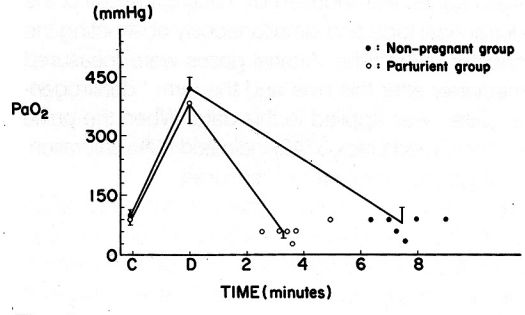

Fig. 2. Changes of PaO_2 following obstructive apnea.

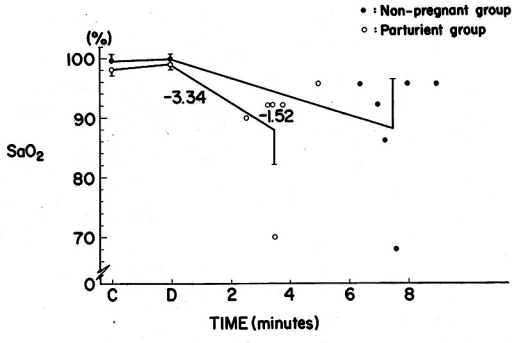

Fig. 1. Oxygen desaturation rate from denitrogenation.

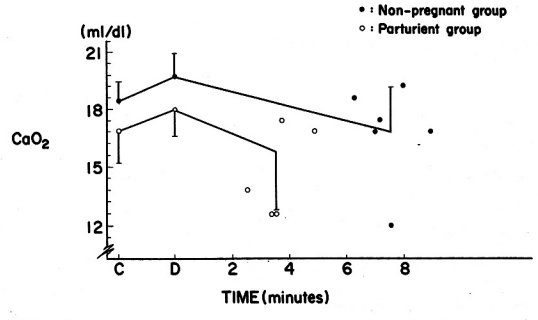

Fig. 3. Changes of arterial oxygen content following obstructive apnea.

At 90% saturation CaO_2 decreased significantly in both groups.

Figure 4 reveals the changes of arterial PCO_2 during apnea. A rapid rise of $PaCO_2$ occured in both groups. The mean rates of rise were slower in the nonpregnant group (2.8 + 1.2 mmHg/min) than in the parturient group (6.8 + 1.8 mmHg/min). These rates of rise in the nonpregnant group are comparable to the values of 3.05 mmHg/min by Eger and Stock et al.

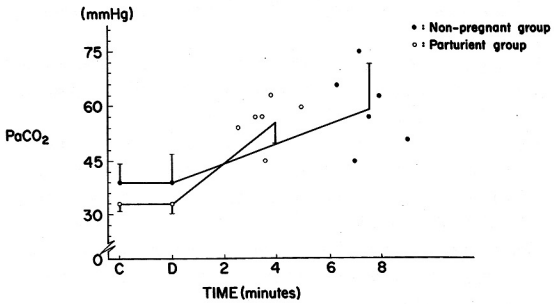

Fig. 4. Changes of $PaCO_2$ following obstructive apnea.

DISCUSSION

Even though all the subjects were denitrogenated effectively, the parturients showed a more rapid decrease in SaO_2 than the nonpregnant group during the obstructive apnea. That is, the slope of desaturation is steeper in the paturients than the nonpregnant group. These results confirmed the report by Archer.

Pregnancy produces significant changes in the respiratory system, some of which alter the oxygen stores in the lungs. Decrease of FRC is most cause of it. The FRC decreases to 15-20% in the gravida at term. It is well established that a large portion of this decrease is due to a reduction in the expiratory reserve volume secondary to the increase in tidal volume. The rate and degree of denitrogenation were also affected by these changes. Parturients denitrogenate more rapidly than non-pregnant women.

Our patients were denitrogenated effectively, but the time required to achieve an exhaled nitrogen concentration of five percent was not measured. Norris et al reported that parturients achieved 95% denitrogenation significantly faster than non-pregnant women (54.5 vs 110.8 sec). This is due to an increase of the respiratory rate and a decrease of the FRC (Byrne et al and Russell et al).

They concluded that either two minutes of tidal breathing or four deep breaths using 8 L/min fresh gas flow provide adequate denitrogenation and similar protection against apneic hypoxemia in normal parturients. The supine position markedly impairs respiratory function in late pregnancy. With tidal volume breathing, there may not be communications between the ambient oxygen and some of the terminal airways throughout the respiratory cycle because one-third to one-half of those the pregnant may develop airway closure during normal tidal breathing in a supine position. Thus, one would expect the pregnant women to be more susceptible to develop an impaired distribution of pulmonary ventilation but this concept has been challenged. Measurements of the closing volume have been made in pregnant women by Bevan et al. They found that the airway closure in a supine position occurred in six of the 20 women during tidal ventilation and that an apparent increase in the closing volume merely represents a fall in the FRC (due to a reduction in the expiratory reserve volume secondary to the increase in tidal volume). Indeed, this closing volume can not be denitrogenated during tidal breathing. In this situation, inspiratory capacity breathing would be of greater benifit because it would open more lung units and allow more complete denitrogenation. In the study of denitrogenation by Carichael et al, there was still about 7% nitrogen remaining in the lungs after four vital capacity breaths. Equivalent nitrogen washout from the lungs to an end-tidal nitrogen content of approximately 6% is achieved by preoxygenation with 100% oxygen for 2 min of tidal breathing and with eight inspiratory capacity breaths. Therefore, we can assume that the degree of denitrogenation of pregnant women may not be affected by the respiratory pattern.

Oxygen uptake in pregnancy markedly increased and is greater than 20% at term compared to the nonpregnant state (Gugell et al). This is due to increased maternal metabolism and increased rate of breathing. The decrease in functional residual capacity, increased oxygen consumption and a possible increased shunt lower the maternal oxygen reserve, making the pregnant laboring women more prone to hypoxia. Accordingly, increasing the FiO_2 in parturients undergoing general anesthesia is essential.

About 25% of the total body O_2 is contained in the lungs, 60% in the blood, and 15% in the tissue (Cherniak et al). However, this condition changes if one breathes 100% oxygen so that the lungs become more important than the blood for storing oxygen.

The minimum arterial oxyhemoglobin saturation

(SaO_2) during obstructive apnea is widely considered to be directly related to apnea duration. Several recent publications have directed attention to two other factors that appear to be related to the rate of fall of the oxyhemoglobin saturation ($dSaO_2/dt$). Studies have shown that minimum SaO_2 for a given duration apnea is dependent upon the thoracic gas volume (TGV) at apnea onset (Fletcher et al). The lower the TGV, the lower the alveolar O_2 stores and, the more rapidly these stores are depleted, the steeper the $dSaO_2/dt$ (Findley et al).

If a normal non-pregnant woman consumes 250 ml of oxygen each minute at rest, 7 min period of apnea could be tolerated in a paralyzed patient if the lung nitrogen were completely replaced by oxygen and assuming a lung functional residual capacity of 1700 ml. At term, a parturient consumes 300 ml/minute of oxygen and 4.5 minutes of apnea could be tolerated assuming a FRC of 1350 ml. Parturients have lower alveolar oxygen stores and these stores are depleted more rapidly than nonpregnant women.

In summary, in this study, creating a single isolated apnea, demonstrates that the rate of oxygen desaturation is faster in parturients than in nonpregnant women. It is suggested that these results are due to a pregnancy-induced increase of the oxygen consumption rate and a decrease in FRC. The results of this study show that induction for term parturients should be speeded up with caution after full oxygenation in comparison with non-pregnant patients.

REFERENCES

Andersen GJ, James GB, Matheres NP: *The maternal oxygen tension and acid-base status during pregnancy. J Obstet Gynecol Brit Common 76:16, 1969.*

Archer GW, Marx GF: *Arterial oxygen tension during apnoea in parturient women. Br J Anesth 46:358, 1974.*

Baldwin GR, Moorthi DS, Whelton JA, MacDonell KF: *New lung functions and pregnancy. Am J Obstet Gynecol 127:235-239, 1977.*

Bevan DR, Holdoroft A, Loh L, MacGREGOR WG, O'SULLIVAN JC, Sykes MK: *Closing volume and pregnancy. Brit Med J 1:13-15, 1974.*

Byrne F, Oruro-Dominah A, Kipling R: *The effect of pregnancy on pulmonary nitrogen wash out. Anesthesia 42:148-150, 1987.*

Carmichael FT, Cruise CJE, Crago RR: *Preoxygenation; A study of denitrogenation. Anesth Analg 68:406-409, 1989.*

Cherniack NS, Longobardo GS: *Oxygen and carbon dioxide gas stores of the body. Physiol Rev 50:196-243, 1970.*

Eger EI, Severinghaus JW: *The rate of rise of $PaCO_2$ in the apneic anesthetized patient. Anesthesiology 22:419-424, 1961.*

Findley LJ, Ries AL, Tisi GM: *Hypoxemia during apnea in normal subjects; mechanisms and impact of lung volume. J Appl physiol 55:1777-1783, 1983.*

Fletcher EC, Kass R, Thornby JI, Rosborough J, Miller T: *Central venous 02 saturation and rate of arterial desaturation during obstructive apnea. J Appl Physiol 66(3): 1477-1485, 1989.*

Gambee AM, Hertzka RE, Fisher DM: *Preoxygenation techniques; comparison of three minutes and four breaths. Anesth Analg 66:468-470, 1987.*

Gugell DW, Frank NR, Gaenaler EA: *Pulmonary function in pregnancy. I. Serial observations in normal woman. Ann Rev Tuberc 67:568, 1953.*

Hanilton WK, Eastwood DW: *A study of denitrogenation with some inhalation anesthetic system. Anesthesiology 16:861-867, 1955.*

Norris MC, Kirkland MR, Torjman MC: *Denitrogenation in pregnancy. Can J Anesth 36(5):523-525, 1989.*

Russell GN, Smith L, Snowdon SL: *Preoxygenation and the parturient. Anesthesia 42:346-351, 1987.*

Stock MC, Schisler JQ, McSweeney TD: *The $PaCO_2$ rate of rise in anesthetized patients with airway obstruction. J Clin Anesth 1(5):328-332, 1989.*

Wattzener SW, King BD: *The rate of arterial oxygen desaturation during apnea in humans. Anesthesiology 20:624-627, 1957.*