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Preoxygenation for Cesarean Section: A Comparison of Two Techniques

MARK C. NORRIS, M.D.,* AND DAVID M. DEWAN, M.D.†

Preoxygenation is routine prior to rapid-sequence induction of general anesthesia for cesarean section. A common method of preoxygenation is 3–5 min of 100% O_2 breathing. In some obstetric emergencies, such as fetal distress, there may not be adequate time for preoxygenation using this technique. Recently, Gold *et al.*[1] showed that four maximally deep inspirations of 100% O_2 within 30 s are as effective as 5 min of inhalation of 100% O_2 in increasing Pa_{O_2} in the nonpregnant patient. The use of this technique in the parturient and its effect on the fetus have not been studied. We, therefore, wished to show that the four-deep-breath, 30-s technique is safe and effective for both mother and fetus.

METHODS

The Clinical Research Practices Committee approved the protocol. Twenty ASA I and II patients scheduled for elective cesarean section under general anesthesia participated in the study, and all patients gave written informed consent. Following premedication with 30 ml 0.3 M sodium citrate, we randomly divided the patients into two groups: Group A was denitrogenated by breathing 100% O_2 for 3 min; Group B was denitrogenated by taking four maximally deep inspirations of 100% O_2 within 30 s. We administered O_2 to both groups at a flow rate of 5–6 $l \cdot min^{-1}$ via a circle anesthesia system and a tight-fitting face mask. We performed a rapid-sequence induction of general anesthesia with thiopental 3.5 $mg \cdot kg^{-1}$ iv followed by succinylcholine 1.2 $mg \cdot kg^{-1}$ iv and intubated the trachea during cricoid pressure. Anesthesia was maintained with 50% nitrous oxide in oxygen and 0.5% halothane until delivery. Paralysis was provided with a 0.1 $mg \cdot ml^{-1}$ infusion of succinylcholine. Ventilation was controlled to maintain end-tidal CO_2 between 4.0 and 4.5%. Three arterial blood samples were drawn from a previously placed 20 gauge arterial catheter: baseline (room air), after preoxygenation, and following intubation. We sampled umbilical cord obtained at delivery. All blood samples were immediately placed on ice and analyzed within 20 min.

We compared the groups for maternal age, weight, height, hemoglobin, smoking history, and weeks gestation. Induction to delivery and uterine incision to delivery intervals and neonatal weights were recorded. A pediatric resident, unaware of the study, assigned Apgar scores. Maternal blood gas values were analyzed using a combined analysis of variance for repeated measures.[2] Other data were analyzed using the Student's t test or chi-squared as appropriate. All values are expressed as mean ± SEM and a $P < 0.05$ was considered significant.

RESULTS

The two groups were similar in age, weight, height, hemoglobin, and weeks gestation (table 1). There were five smokers in Group A and three smokers in Group B. Induction to delivery times and uterine incision to delivery times were similar (table 1).

Maternal blood gas values are shown in table 2. There were no differences in maternal blood gas values between the two groups at any time.

Neonatal outcomes were also similar. Neonatal weight was 3.3 ± 0.2 kg in Group A and 3.4 ± 0.2 kg in Group B. No infant had an Apgar score of less than 7 at 1 or 5 min. Umbilical artery and venous blood gas values were similar in the groups (table 2).

TABLE 1. Patient Data

	Group A* (3 min) (n = 10)	Group B* (4 breath) (n = 10)
Age (yr)	25.3 ± 1.9	23.7 ± 1.7
Weight (kg)	75.0 ± 3.8	73.4 ± 4.1
Height (cm)	163.7 ± 2.5	155.7 ± 2.4
Hemoglobin (g/dl)	11.4 ± 0.4	12.5 ± 0.5
Gestation (wk)	38.9 ± 0.2	38.3 ± 0.5
No. smokers	5	3
Induction to delivery (min)	7.1 ± 0.8	5.6 ± 0.5
Uterine incision to delivery (s)	75.5 ± 7.9	66.6 ± 11.9

* Values are mean ± SEM.

* Fellow, Obstetric Anesthesia.

† Associate Professor of Anesthesia.

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Address reprint requests to Dr. Norris: Department of Anesthesiology, Grady Memorial Hospital, 69 Butler Street, SE, Atlanta, Georgia.

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TABLE 2. Blood Gas Values

	Group A* (3 min) (n = 10)	Group B* (4 breath) (n = 10)
Baseline		
*p*H	7.44 ± 0.0	7.44 ± 0.01
Pa_{CO_2}	31.4 ± 0.7	31.7 ± 0.5
Pa_{O_2}	100.9 ± 3.1	102.5 ± 1.5
After Preoxygenation		
*p*H	7.44 ± 0.01	7.46 ± 0.01
Pa_{CO_2}	31.9 ± 0.4	31.7 ± 0.8
Pa_{O_2}	385.0 ± 23.6*	404.2 ± 15.2*
Following intubation		
*p*H	7.37 ± 0.0†	7.37 ± 0.01†
Pa_{CO_2}	40.0 ± 0.7†	40.6 ± 0.7†
Pa_{O_2}	270.9 ± 33.7†	305.8 ± 24.5†
Umbilical		
*p*H	7.35 ± 0.01	7.36 ± 0.01
P_{CO_2}	43.5 ± 1.6	43.6 ± 1.0
P_{O_2}	33.9 ± 1.9	37.8 ± 2.3
Umbilical artery		
*p*H	7.31 ± 0.01	7.33 ± 0.01
P_{CO_2}	50.7 ± 1.5	50.7 ± 0.7
P_{O_2}	17.8 ± 1.4	22.0 ± 1.4

* Values are mean ± SEM.
† $P < 0.01$ *versus* baseline.
‡ $P < 0.01$ *versus* after preoxygenation.

DISCUSSION

Oxygenation during anesthesia has been studied for many years. Dillion and Darsie[4] observed that significant desaturation of arterial blood occurs during the apnea that accompanies thiopental induced anesthesia. They noted that oxygen administration avoided this desaturation and recommended 5 min of preoxygenation before induction and endoscopy. Hamilton and Eastwood[5] showed that denitrogenation was 95% complete within 2–3 min of tidal breathing using a circle anesthesia system with a 5 $l \cdot min^{-1}$ flow. These studies led to the recommendation in standard anesthesia texts of 3–5 min preoxygenation prior to rapid-sequence induction of anesthesia.[6,7] Heller and Watson[3] showed, in a spontaneously ventilating nonpregnant patient that 3–4 min of 100% oxygen breathing are required to increase Pa_{O_2} from 78 to greater than 300 mmHg. However, in an artificially ventilated patient, the Pa_{O_2} increased from 95 to higher than 400 mmHg within 30 s. These observations led Gold *et al.*[1] to develop and study the four-deep-breath, 30-s technique of preoxygenation. They demonstrated that arterial oxygen tension in normal unanesthetized, patients is similar after four maximally deep inspirations within 30 s and after 5 min of 100% oxygen breathing. Although Archer and Marx[9] found that the reduction in oxygen tension during apnea under general anesthesia is significantly greater in pregnant women than in nonpregnant controls, in some emergency circumstances, there is not sufficient time for a full 3–5 min of preoxygenation and the four-deep-breath, 30-s technique would be useful.

Pregnancy produces significant anatomic functional changes in the respiratory system, which may alter the response of the parturient to the four-deep-breath, 30-s technique. While total lung capacity remains unchanged, there is a decrease in expiratory reserve volume and residual volume, resulting in an overall 9.5–25% decrease in functional residual capacity (FRC).[10–13] These changes decrease the parturient's oxygen reserve at end expiration and this, associated with the increase in oxygen consumption seen in pregnancy,[10] means the parturient rapidly becomes hypoxemic during periods of apnea.[9] However, this decrease in FRC also decreases nitrogen reserve in the lung, and nitrogen washout should occur more rapidly than in the nonpregnant patient. The role of airway closure also must be considered. While studies of closing capacity (CC) or closing volume conflict, most investigators find a decrease in the difference between FRC and CC such that airway closure occurs more frequently in the pregnant patient during tidal breathing,[12–16] especially when supine.[13,14,17,18] Continued perfusion of these now underventilated alveoli may explain the supine hypoxemia and increased alveolar–arterial oxygen tension difference seen in some parturients at term.[18] In such a patient in whom CC does encroach upon FRC while supine, the four-deep-breath, 30-s technique may be expected to improve oxygenation by increasing tidal volume and reexpanding previously underventilated alveoli. Our data are consistent with these suppositions.

We also felt it important to assess the effect of the four-deep-breath, 30-s technique on fetal oxygenation. Investigators have shown that increased umbilical P_{O_2} correlates significantly with improved fetal outcome as measured by Apgar scores, time to sustained respiration, or umbilical acid–base status.[19–21]

Shelley and Gutsche[22] state that 6 min of oxygen inhalation is required for equilibration of maternal/fetal oxygen levels. The four-deep-breath, 30-s technique may expose infants to increased oxygen levels for less than 6 min, however, work by other investigators suggests that less time is needed for maternal oxygen inhalation to affect fetal P_{O_2} [23,24] Myers *et al.*,[23] studying Rhesus monkeys, showed that maternal administration of oxygen increases fetal tissue P_{O_2} beginning within 60 s and equilibrating with 3 min. Longo and Power[24] constructed a systems model of placental O_2 transfer and suggest that fetal oxygen levels completely respond within 75 s to changes in umbilical oxygen supply. The patients in the four-deep-breath, 30-s group were exposed to oxygen for a mean of 6 min before delivery, and their infants had an umbilical vein P_{O_2} (37.8 ± 2.3 mmHg) similar to that of the infants in the 3-min group

(33.9 ± 1.9 mmHg) whose mothers were exposed to oxygen for at least 10 min before delivery. In one case, the total time from preoxygenation to delivery was only 3 min and the umbilical vein P_{O_2} was 41.4 mmHg. These results agree with those of Myers *et al.*[23] and Longo and Power[24] and demonstrate that in the normal situation fetal P_{O_2} responds rapidly to changes in maternal Pa_{O_2}. In circumstances of fetal distress, there are often severe limitations on the amount of oxygen that can be transferred to the fetus with any technique of preoxygenation and our prime concern is to maintain adequate maternal oxygenation during the apnea that accompanies induction and intubation.

In conclusion, we have shown that in the parturient both 3 min of oxygen breathing and the four-deep-breath, 30-s technique are adequate for preoxygenation prior to rapid sequence induction of general endotracheal anesthesia for cesarean section. We have also shown that both techniques provide similar fetal outcomes. Therefore, the four-deep-breath, 30-s technique can be used safely for routine obstetric anesthetics and may be particularly useful in the parturient who is unable to tolerate a close-fitting face mask for a prolonged period of time. However, we believe that its main application should be in those situations, such as acute fetal distress, where time is of the essence.

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