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(Accepted for publication January 25, 2000.)

Anesthesiology
2000; 92:1845

Preoxygenation: Comparison of Maximal Breathing and Tidal Volume Techniques

To the Editor:—Baraka *et al.*[1] recently demonstrated that preoxygenation using eight deep breaths within 60 s (8 DB/60 s) at an oxygen flow of 10 L/min can produce arterial oxygen tension (Pa_{O_2}) values comparable to those obtained using normal tidal volume breathing (TVB) for 3 min. In addition, they showed that this technique significantly delayed the onset of apnea-induced hemoglobin desaturation.

Before this new method becomes widely accepted, several issues need to be clarified. First, we wonder what role the baseline values for Pa_{O_2} played in the delayed hemoglobin desaturation after 8 DB/60 s. For this portion of their study, Baraka *et al.* used a separate group of subjects, group B, in whom baseline Pa_{O_2} values were 407 ± 53 mmHg after 3 min of TVB and 434 ± 45 mmHg after 8 DB/60 s. Both values were higher than those of subjects in group A, in whom 3 min of TVB yielded a Pa_{O_2} higher than 392 ± 72 mmHg *versus* 369 ± 69 mmHg after 8 DB/60 s. It cannot be ruled out that the higher Pa_{O_2} values observed in in group B after 8 DB/60 s contributed to the delay in hemoglobin desaturation. If subjects from group A were subjected to apnea, the benefit of 8 DB/60 s may not have been evident, or at least may not have been as dramatic.

Second, we think that reporting this technique as eight breaths in 60 s underestimates the number of breaths and the time of preoxygenation. If we understand the protocol correctly, after the eight breaths, a rapid-sequence induction of anesthesia was carried out. During this period, face-mask oxygenation was continued until apnea ensued, a period described as 15 to 30 s during which an additional 2 to 4 deep breaths occurred. Thus, it appears that Baraka *et al.* actually evaluated the efficacy of 10 to 12 breaths during a 75 to 90 s period rather than eight deep breaths in 60 s. The authors proposed two possible mechanisms for the delayed decrease in hemoglobin saturation during 8 DB/60 s: (1) that the extra 15 to 30 s provided more alveolar oxygenation in patients breathing deeply for 60 s than during TVB; and (2) that continued deep breathing during this extra time may have opened collapsed airways or lung tissue, with a consequent increase in oxygen store in the functional residual capacity. In his editorial, Benumof[2] proposed other explanations, including a leftward shift of oxyhemoglobin dissociation curve secondary to hyperventilation-induced reductions in Pa_{CO_2}. We propose that by extending the duration of deep breathing beyond 60 s (*i.e.,* to 75-90 s) may have enhanced the potential influence of this factor. A delay in desaturation caused by a leftward shift of the oxyhemoglobin dissociation curve would not necessarily favor improved oxygen transport. Because the authors presented only values for Pa_{O_2}, the role of changes in arterial carbon dioxide tension and arterial pH must remain speculative.

Third, Baraka *et al.* state that using the technique of four deep breaths in 30 s (4DB/30 s), Pa_{O_2} values increased exponentially as oxygen flow is increased from 5 to 10 to 20 L/min. Although this description may accurately describe the increase from baseline values, the mean values for Pa_{O_2} at 5, 10, and 20 L/min oxygen flow all decrease within the linear, essentially flat portion of the curve. The differences appear minimal, and the authors make no statement concerning the significance of the differences among the values for Pa_{O_2} at the three fresh gas flows. Recently, Nimmagadda *et al.*[3] demonstrated that increasing fresh gas flows from 5 to 7 to 10 L/min had no significant effect on end-tidal oxygen or nitrogen during preoxygenation using 4DB/30 s or 2-min TVB techniques in healthy volunteers. Although Nimmagadda *et al.*[3] did not test 20 L/min, this value is probably not encountered in most circumstances in the operating room. Although interesting and provocative, the study of Baraka *et al.* is far from conclusive. More studies are required to ascertain if the 8 DB/60 s method actually delays hemoglobin desaturation, and whether this method is more beneficial than the traditional TVB. It is clearly premature to anoint the 8 DB/60 s technique as the method of choice for preoxygenation.

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(Accepted for publication January 25, 2000.)

Anesthesiology
2000; 92:1846

In Reply:—Drs. Morrison and Videira make the valid point that pediatric patients desaturate faster than adults and that preoxygenation is especially indicated in several types of pediatric patients. In fact, I have previously reported complete apnea-oxyhemoglobin desaturation curves for various humans using computer modeling[1] and have showed that a 10-kg pediatric patient will desaturate twice as fast as a 70-kg adult. Rather than offer a convoluted explanation as to how the words "obvious exclusion examples" were chosen, I agree the phrase is too broad and that Dr. Morrison provides examples of two patients who deserve to be preoxygenated.

Dr. Salem *et al.* are probably correct with their hypothesis that Baraka *et al.* actually studied 10 to 12 deep breaths in 75 to 90 s rather than eight deep breaths in 60 s. In ongoing studies I have tried to repeat the Baraka *et al.* methodology. Even with extensive preoxygenation coaching of the patients, I have found that the preoxygenation process is always extended by at least 2 breaths beyond the intended period. In fact, if one wants to study eight deep breaths in 60 s, then the rapid sequence induction must be begun on the inspiratory limb of the sixth breath. I agree with the Salem *et al.* comment regarding the effect of an extended period of hyperventilation on shifting the oxyhemoglobin curve further to the left.

In summary, I thank Drs. Morrison, Videira, and Salem for their thoughtful insights.

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(Accepted for publication January 25, 2000.)

Anesthesiology
2000; 92:1846-7

In Reply:—Thank you for referring to me the letter from Dr. Salem regarding our report, "Preoxygenation: Comparison of Maximal Breathing and Tidal Volume Techniques."[1] The arterial oxygen tension (P_{O_2}) at the end of the traditional technique of preoxygenation or after using the eight-deep-breaths technique was not significantly different in group A or in group B. However, both techniques of preoxygenation resulted in Pa_{O_2} values that were significantly higher than those achieved after using the four-deep-breaths technique.

Using the four-deep-breaths technique, P_{O_2} at the end of preoxygenation was significantly increased by increasing the oxygen flow from 5 L/min (256 ± 73 mmHg) to 20 L/min (317 ± 67 mmHg). The report does not recommend the use of 20 L/min O_2 for preoxygenation. Although the report shows that such a high flow improves preoxygenation by the four-deep-breaths technique, it does not suggest that this technique can achieve the P_{O_2} levels achieved by the traditional ventilation technique or by the eight-deep-breath technique.

Ventilation volume per minute (tidal volume × respiratory rate/min) is the main factor that determines arterial carbon dioxide tension. The minute ventilation volume resulting from eight-deep-breaths (of approximately 1000 ml) per minute is approximately equal to the volume that is achieved using traditional tidal volume breathing of 500 ml at a rate of 14 to 16 breaths per minute. Thus, we cannot explain the adequate preoxygenation achieved by the eight-deep-breaths technique by a lower arterial carbon dioxide tension value.

Our report considers the time of preoxygenation using the different techniques as the time of preoxygenation before rapid-sequence induction of anesthesia. Whatever technique of preoxygenation is used, the face-mask oxygenation must be maintained until complete apnea is achieved to avoid the breathing of air that counteracts the rationale of preoxygenation. A major reason for inadequate preoxygenation is the premature removal of the face mask or a leak under the mask that allow the inspiratory entrainment of room air.[2]

In conclusion, our report shows that preoxygenation using the eight-deep-breaths technique for 60 s is superior to the four-deep-breaths technique for 30 s. The report does not claim that the eight-deep-breaths technique is the method of choice for preoxygenation, and only recommends that the technique can be used as an alternative to the traditional technique of preoxygenation in patients undergoing rapid-sequence induction of anesthesia and in other circumstances in which tracheal intubation or ventilation may be difficult to achieve.

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