Pursuing the Importance of Postoperative Atelectasis

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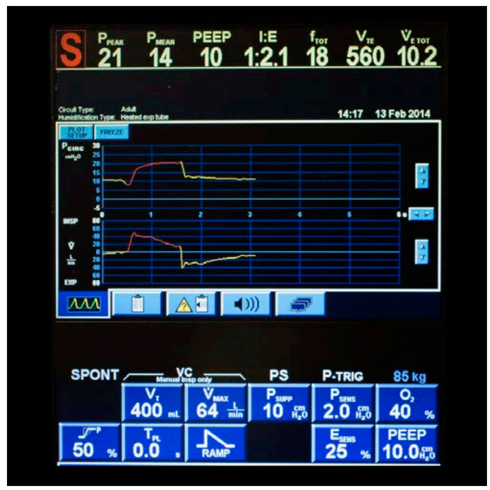
Atelectasis develops shortly after preoxygenation and induction of general anesthesia and impairs oxygenation by creating an intrapulmonary shunt. The pioneering use of computed tomography by Professor Göran Hedenstierna and collaborators in the 1980s[1] opened the way to understanding the pathophysiology of perioperative atelectasis. Atelectasis occurs in most anesthetized patients, generally affecting a small portion of dependent lung regions, but is more conspicuous in certain conditions such as patients who are overweight, have abdominal distention, or are in the Trendelenburg position.[2] Atelectasis may persist after surgery and may contribute to the development of postoperative pulmonary complications.[3]



"[What is] the link between optimal ventilatory strategies and a reduced incidence of postoperative pulmonary complications?"

Atelectasis during general anesthesia may be prevented by limiting the fraction of inspired oxygen ([F_{IO_2}] "absorption atelectasis")[4] and by promoting alveolar recruitment with positive end-expiratory pressure (PEEP) and recruitment maneuvers.[5] The effectiveness of these interventions has been thoroughly investigated during induction and maintenance of anesthesia. However, the same conditions that contribute to early formation of atelectasis are often present during, and shortly after, emergence from anesthesia. Therefore, ventilatory strategies during emergence may counteract evidence-based strategies used intraoperatively, facilitating the development of postoperative atelectasis.

In this issue of Anesthesiology, Jeong *et al.*[6] report the results of a clinical trial comparing the effects of pressure support ventilation with PEEP *versus* spontaneous ventilation during anesthetic emergence on postoperative atelectasis. In this randomized study, blinded to investigators of lung ultrasound and outcome assessments, 100 nonobese patients undergoing laparoscopic colectomies or radical prostatectomy received either the intervention of 5 cm H_2O pressure support over 5 cm H_2O PEEP throughout emergence, or the control where ventilation was provided manually as needed, without PEEP. Emergence was 8 to 9 min on average and F_{IO_2} was 0.4 in both groups. The main finding of the study is that maintaining a consistent positive pressure at the airway with pressure support and PEEP during emergence from general anesthesia results in lower incidence of atelectasis (measured by lung ultrasonography) and higher P_{AO_2} in the postanesthesia care unit. Unfortunately, but not unusually, no significant effect was detected in reducing the number of episodes of desaturation (S_{AO_2} less than 92%) nor of any predetermined clinical outcomes up to 48 h postoperatively.

More detailed information regarding the precise method of manual ventilation in the control group, especially the level of positive pressure, would have helped understanding to what extent the study groups differed in treatment other than in PEEP level. Also, the authors choice to omit preoxygenation before emergence is somewhat surprising: similar to the induction of anesthesia, increasing F_{IO_2} before extubation is a safeguard against the consequences of a problematic extubation. Finally, the quantitative difference in atelectasis between the two groups (table 2 in Jeong *et al.*[6]) is somewhat indistinct: while the number of atelectatic segments is significantly lower in the intervention group, the difference in atelectasis score does not reach significance. Regardless of these possible shortcomings, the study from Jeong *et al.*[6] is important for several reasons.

First, maintaining a consistent positive pressure at the airway throughout emergence from anesthesia for laparoscopic procedures limits the development of postoperative atelectasis. While numerous studies have demonstrated the

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beneficial effects of PEEP, individualized or not, during maintenance of anesthesia, the current study reminds us that this practice should be continued during emergence. From a physiologic point of view, and in accordance with the findings of the study, it is important to avoid airway closure and the development of areas with low ventilation/perfusion ratios (susceptible to atelectasis formation) during the entire course of anesthesia. This can be done by maintaining PEEP during emergence, with or without inspiratory support.

Second, Jeong *et al.*[6] limited FIO_2 to 0.8 during induction and 0.4 during maintenance and emergence, even with unexpected difficult intubations in nine study subjects. Given that the FIO_2 was equal between study groups, it is impossible to speculate on its effects on the development of atelectasis. The issue of FIO_2 on emergence remains an open one. Currently, we can only state that when concerns exist on the ability of a patient to maintain adequate oxygenation postoperatively because of difficult airway, morbid obesity, and obstructive sleep apnea, among others, an FIO_2 of 1 is indicated and recommended. In healthy patients undergoing nonabdominal procedures where a PEEP of 7 to 9 cm H_2O was maintained throughout the surgery, an FIO_2 of 1 during awakening did not produce clinically significant atelectasis.[7] This raises the question why one would refrain from emergence preoxygenation even in low-risk patients.

Third, computed tomography remains the accepted standard when measuring atelectasis. However, exposure to radiation and the need to transport the anesthetized or newly operated patient to the radiology department limits its use. Jeong *et al.*[6] used the still developing technique of ultrasonography, with its advantages of being portable, dynamic, and free of radiation. Lung ultrasound is judged to be reliable in detecting postoperative atelectasis, and one of several proposed scores has been shown to correlate with the volume of atelectasis measured by computed tomography.[8] Here, Jeong *et al.* looked at the incidence of atelectasis, and compared the number of patients in each group having a positive sign of atelectasis in more than 3 out of 12 examined lung sections. The numbers give a perhaps less intuitive appreciation of the extent of atelectasis formation and emphasizes that a standardized scoring system for lung ultrasound and atelectasis would be much welcomed.

A clear continuum between atelectasis and postoperative pulmonary complications is still elusive. Despite years of excellent research, the link between optimal ventilatory strategies and a reduced incidence of postoperative pulmonary complications does not consistently include preventing atelectasis. Despite much script and some important experimental data,[9] the clinical evidence is yet to come. Nearly 4 decades after the visual demonstration of atelectasis by chest computed tomography in humans undergoing general anesthesia, the knowledge in this field is orders of magnitude greater. However, we still need to add important pieces to the story to be able to link the prevention of atelectasis to the ability to improve outcomes. A possible feature of this process is the use of dynamic imaging that may complement what we know from computed tomography studies with a real-time exam with technologies such as ultrasonography and electrical impedance tomography. The study of Jeong *et al.* constitutes a small but significant building block in this trail.

Competing Interests

The authors are not supported by, nor maintain any financial interest in, any commercial activity that may be associated with the topic of this article.

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