Host: Welcome to the Anesthesiology journal podcast, an audio interview of study authors and editorialists.

Dr. BobbieJean Sweitzer: Hello. I’m BobbieJean Sweitzer, Professor of Anesthesiology at Northwestern University and an Associate Editor for Anesthesiology, and you are listening to an Anesthesiology podcast designed for physicians and scientists interested in the research that appears in our journal.

Today we are speaking with two authors of publications that appear in the October 2019 issue of the journal. With us is Dr. Erland Östberg, Dr. Östberg is the lead author of an article titled “Positive End-expiratory Pressure and Postoperative Atelectasis.” He is a Ph.D. and Senior Consultant in the Departments of Anesthesia and Intensive Care Medicine in Västerås in Köping Hospital, Sweden. Welcome, Dr. Östberg.

Dr. Erland Östberg: Thank you. It’s a pleasure to join you for this podcast.

Dr. BobbieJean Sweitzer: And joining Dr. Östberg is Dr. Karen B. Domino who wrote an accompanying editorial “Pre-emergence Oxygenation and Postoperative Atelectasis.” Dr. Domino is Professor of Anesthesiology and Pain Medicine, University of Washington in Seattle, Washington. And welcome, Dr. Domino.

Dr. Karen B. Domino: Thanks so much. I’m delighted to participate in this discussion of this very interesting article.

Dr. BobbieJean Sweitzer: So, Dr. Östberg, let’s start with you. When I entered the title of your article “Positive End-expiratory Pressure and Postoperative Atelectasis” into Google, I’ve got 160,000 hits. Can you tell me what question you tackled that has not already been answered by previous research in this field?

Dr. Erland Östberg: Well, a lot of research in this field has studied atelectasis formation early after induction and effects of positive end-expiratory pressure—PEEP—intraoperatively. But emergence from anesthesia in ventilatory settings during this phase has drawn very little attention.

We think that the awakening procedure might play a role in the development of postoperative atelectasis and postoperative pulmonary complications and in this study we wanted to examine the specific effects of PEEP during this phase and actually the effects of withdrawing PEEP before emergence and extubation.

Dr. BobbieJean Sweitzer: So, withdrawing PEEP before extubation to me seems a bit counterproductive. Doesn’t PEEP actually prevent atelectasis?

Dr. Erland Östberg: Yes, that’s correct. PEEP applied after induction reduces the formation of intraoperative atelectasis. It does so by increasing the end-expiratory lung volume and by counteracting airway closure, especially in the dependent parts of the lungs.

Now, during awakening and before extubation we normally preoxygenate our patients again and if PEEP is maintained during this phase, we will get a high oxygen concentration in these dependent lung regions.

At the moment of extubation, PEEP is discontinued and these lung regions will then be susceptible to the formation of postoperative atelectasis. So, paradoxically, although PEEP has protective effects during maintenance of anesthesia, it might be that it has negative effects if used during emergence preoxygenation and awakening, but we don’t know the importance of this mechanism yet.

Dr. BobbieJean Sweitzer: Dr. Domino, how effective is PEEP in preventing atelectasis, at least intraoperatively?

Dr. Karen B. Domino: Well, Dr. Östberg published a study that was published in Anesthesiology last year in 2018 on the subject and what he found is 7 to 9 cm H2O of PEEP in healthy, nonobese patients significantly reduced the amount of atelectasis. This group is one that has relatively small amounts of atelectasis, but the amount of reduction was at least about 60%, 70% reduction in the atelectasis formation.

And also, interestingly, that the PEEP prevented problems with oxygenation and carbon dioxide elimination that might occur due to ventilation perfusion mismatch associated with the development of atelectasis. So, it appears to be quite effective in reducing atelectasis intraoperatively but doesn’t take it away completely.

Dr. BobbieJean Sweitzer: So, Dr. Östberg, how did you actually measure atelectasis?

Dr. Erland Östberg: Well, in this study we used computer tomography scans before and after awakening and measured the atelectasis area in a single-sliced transverse scan just above the diaphragm.

Dr. BobbieJean Sweitzer: Interesting. So, while they were still anesthetized?

Dr. Erland Östberg: Yes. The first scan was obtained still anesthetized before awakening and then we took a second scan approximately 30 minutes after awakening.

Dr. BobbieJean Sweitzer: So, can you tell us a bit more about these patients, like what types of surgeries were they having? What type of anesthesia?

Dr. Erland Östberg: Well, in this trial we studied healthy, normal-weight patients undergoing general anesthesia for a day-case surgery and it was mostly inguinal hernia repair and we used total intravenous anesthesia and all patients were intubated and mechanically ventilated.

Dr. BobbieJean Sweitzer: So, I believe I noticed that just one of the 30 patients that you studied were female. Any particular reason for that?

Dr. Erland Östberg: Well, that is correct. It wasn’t intentional, but a consequence of the inguinal hernia being a very common type of surgery in our day-case unit. An inguinal hernia is much more common among men. Importantly, there are no studies this far indicating that there would be any difference in atelectasis formation between sexes.

Dr. BobbieJean Sweitzer: Dr. Domino, what effects does general anesthesia have on pulmonary function?

Dr. Karen B. Domino: Well, general anesthesia reduces the resting lung volume due to a loss of muscle tone and the functional residual capacity, or the lung volume at the end of expiration, decreases below the closing capacity where the airways begin to close.

What that leaves is trapped gas in the areas where the airways are closed and that is absorbed and as it’s absorbed, atelectasis occurs and it occurs predominantly in the dependent lung regions near the diaphragm and it’s found in about 90% of patients.

Dr. BobbieJean Sweitzer: So, Dr. Östberg, did you exclude patients with preexisting pulmonary disease? And if so, how exactly did you identify those conditions for exclusion?

Dr. Erland Östberg: Yes. We wanted to study the effects of PEEP and anesthesia without interference from any preexisting pulmonary disease. So, from the patient’s medical history we excluded smokers and subjects with symptomatic obstructive pulmonary disease.

On the day of surgery, we performed a simple spirometer test to verify this and we also ensured peripheral oxygen saturation at 96% or higher breathing room air.

Dr. BobbieJean Sweitzer: And what were the ventilatory parameters that you employed for these patients? I think you said they were all intubated, all had general anesthetics.

Dr. Erland Östberg: Yes, that’s correct and the two study groups had identical ventilatory settings until starting the awakening procedure. So, we used...
a tidal volume of 7 ml/kg ideal body weight and PEEP 7 or 9 cm H₂O with the highest setting in case body mass index was between 25 and 30 kg/m². The inspired oxygen concentration during maintenance was 35%.

Dr. BobbieJean Sweitzer: And they all had the same endotracheal tubes?

Dr. Erland Östberg: Yes, they did.

Dr. BobbieJean Sweitzer: So, wasn’t it challenging to actually get computer tomography scans on these patients, like right before and then soon after their emergence from general anesthesia? How did you effectively do this in this day-surgery unit?

Dr. Erland Östberg: Yes, thank you for asking that question. I must admit that it’s a bit challenging, actually, to perform a study like this, but I think that two factors made it easier. Firstly, our research group has done several clinical studies now that include computed tomography scans on anesthetized or recently anesthetized patients.

Secondly, our study site, Köping Hospital, is a small hospital where we only do day-case surgery and mainly elective radiology. The Radiology Department is located directly below the operation theatres. So, it’s a short elevator ride to reach the CT scanner.

And I think that we have become pretty skilled by now getting safely in and out of the CT with an anesthetized patient without disturbing the ordinary activity down there too much and we take great care in maintaining our good relations with the Radiology Department.

Dr. Karen B. Domino: I just wanted to add that this group has done a phenomenal amount of research in this area and it really amazing. And so, I was very excited to be able to see this recent article. I think you guys first started doing it maybe 25 years ago or 30 years ago, is that correct?

Dr. Erland Östberg: Yes, that’s correct. Actually Dr. (Heddingkrana) and his group, they started in the early 1980’s.

Dr. BobbieJean Sweitzer: Thanks for pointing that out, Dr. Domino, because that is just sort of amazing in and of itself, that many years and this much good data and information and even being able to effectively deal with these kinds of studies. It takes just the right people and the right place and the right coordination.

So, Dr. Domino, turning back to you for a moment, are there certain procedures or positions during anesthesia and surgery or even characteristics of patients who are more likely to develop atelectasis under general anesthesia?

Dr. Karen B. Domino: Well, patients who are undergoing under intrabdominal or thoracic surgery or cardiopulmonary bypass are more likely to develop greater amounts of atelectasis. I would suspect working up near the diaphragm, underneath the diaphragm in the supine position might be more of an issue in the patients, more atelectasis in that location as opposed to a lower abdominal procedure.

Also, it’s patients with preexisting pulmonary disease advanced stage and certainly morbid obesity may very well be at higher risk as well.

Dr. BobbieJean Sweitzer: And what about Trendelenburg positioning?

Dr. Karen B. Domino: Oh, yes. I’m a neuroanesthesiologist (laughter) so that’s not a position we standardly use, but Trendelenburg position would certainly be a high-risk position as well, especially for those where the patient is almost on their head in that procedure and the legs are up and that just pushes up the diaphragm and compresses the lungs.

Dr. BobbieJean Sweitzer: So, you do the cases prone and what about prone positioning? Because isn’t like, for example, for a certain ARDS in ICUs they actually recover patients in those kinds of positions or treat them to improve lung dynamics? Is prone better or worse or any different for atelectasis than supine?

Dr. Karen B. Domino: Well, the prone position does improve ventilation and profusion matching. In addition, depending on how you’re positioning the patient, particularly with the more recent tables where the abdomen is much more freer in that, you can actually have improved ventilation profusion matching, even in the normal lung aestheticized (insensible) actually worked on animals in normal situations.

Dr. BobbieJean Sweitzer: So, Dr. Östberg, did you assess anything other than radiographic evidence about atelectasis? Were there other kinds of parameters that you were assessing on these patients?

Dr. Erland Östberg: Yes, we used the arterial blood gases to evaluate the oxygenating capacity of the lungs and blood gases were sampled both before induction and before and after emergence.

Dr. BobbieJean Sweitzer: Interesting. So, did you have any problems convincing your Research Ethics Committee or even these patients that it was safe to have clinically unindicted CT scans and arterial lines?

Dr. Erland Östberg: No, in fact we had no problems, neither with the Ethics Committee nor the patients. Any why not? I believe that we are very conscious about these important aspects and I’m glad that you bring them up. We provided both the Ethics Committee and the patients with full insight and thorough information about the study and radiation exposure was kept to a minimum because we did not perform any full thoracic CT scans.

We obtained an initial frontal scout view and, as I mentioned earlier, only one transverse scan close to the diaphragm; therefore, the total radiation from these two CT scans were a lot less and, in fact, only approximately 1/10th compared to a standard thoracic CT scan.

Before the study, these aspects were carefully evaluated in collaboration with our radiologist and the local Radiation Safety Committee and also the arterial lines were inserted under local anesthesia.

Dr. BobbieJean Sweitzer: Well, thank you for all of this effort and thank you to these patients for helping us advance science.

Dr. Domino, is atelectasis harmful or is it just an incidental finding that we talk about?

Dr. Karen B. Domino: Well, the big concern for anesthesiologists is that atelectasis causes ventilation profusion mismatch and increased pulmonary shunting which creates hypoxemia and it can also cause with that impaired carbon dioxide elimination.

So, we would see this clinically and say patients who are morbidly obese perhaps in that steep Trendelenburg position that that can actually see that with needing a higher FiO₂ to be able to oxygenate the patients.

However, even more concerning with the evidence that the atelectasis persists in the postoperative period especially after major surgery, it may contribute to postoperative pulmonary complications and there’s some experimental evidence that suggests that atelectasis may have a role in postoperative pneumonia.

Dr. BobbieJean Sweitzer: So, Dr. Östberg, can you summarize for us what you found in this study?

Dr. Erland Östberg: Well, we studied withdrawing PEEP before emergence preoxygenation and awakening and compared withdrawing PEEP with our control group who had a maintained PEEP and we had no difference between the groups when evaluating the changing atelectasis from before to after awakening.

So, for this patient group, withdrawing PEEP does not reduce the amount of postoperative atelectasis; however, by doing a CT scan both before and after awakening, we could also, I believe, for the first time really get a number of how much the awakening procedure contributes to the postoperative atelectasis in this patient group.
And we could see that as long as you have normal or almost normal pulmonary function and an open lung before awakening, this patient group tolerated 100% oxygen while during awakening.

So, we could see that this group actually has quite small atelectasis postoperatively and we believe that that is an important finding, but it has been some discussion on whether or not you should preoxygenate patients before awakening.

Dr. BobbieJean Sweitzer: I do think, though, that you had some patients who were outliers, right? Meaning that they did develop larger areas of atelectasis? What were some of the preexisting characteristics of these patients?

Dr. Erland Östberg: Well, that is correct. We had some outliers and, unfortunately, we could not identify any obvious characteristics contributing to larger atelectasis in these outliers. We have observed this also in previous studies, mainly that some patients developed larger atelectasis, but we don’t really know why. And this remains an interesting and important subject for future research.

Dr. BobbieJean Sweitzer: And what types of patients do you anticipate may have a different outcome than you found in this study of relatively healthy patients having ambulatory surgery relatively, I assume, short surgeries some distance from the diaphragm, some of the sort of things that are counter to what Dr. Domino had mentioned that typically sort of increase the risk of atelectasis?

Dr. Erland Östberg: We think that any patient, actually, who is not capable of restoring their ordinary lung volume in their early postoperative phase may be at greater risk and this includes, for example, overweight patients and patients undergoing major abdominal surgery, especially those with inadequate pain control.

Many of these patients also require a higher PEEP level during surgery which would aggravate any possible negative effects of maintaining PEEP during emergence preoxygenation.

It should be emphasized, though, that we haven’t studied this yet so we don’t know for sure. Although we’re now planning to perform a study in this patient group.

Dr. BobbieJean Sweitzer: Well, we look forward to that study and more information from your group.

Dr. Domino, what role does 100% FiO2 play in causing atelectasis and particularly contrasting it with, say, 80%? Or we’ve talked a bit about preoxygenation before and then before patients get ready to be extubated we put them back on 100%. Can you talk about that issue?

Dr. Karen B. Domino: Sure. Well, with 100% oxygen the gas behind the enclosed airways is very rapidly absorbed and this causes alveolar collapse in atelectasis. The oxygen just is really well-absorbed from these alveoli and this is why our pulmonary medicine colleagues have always asked me why in the world we in anesthesiology are always preoxygenating a patient or during prior to emergence.

In contrast, nitrogen we know is poorly soluble in the plasma and it’s very slowly absorbed from the areas behind the closed airways. So, with the 100% oxygen you’ll be creating atelectasis that might have disappeared during the procedure with the use of PEEP and a lower FiO2. So, this is kind of the problem.

Dr. BobbieJean Sweitzer: So, I want to follow up on that, but before that I was to ask Dr. Östberg another question about this issue of 100% FiO2, Dr. Östberg, have studies sort of similar to what you did been done looking at less than 100% FiO2 both, I guess, with and without PEEP at the time of extubation? And if so, what have they shown?

Dr. Erland Östberg: Yes, there are a few studies that have investigated this and as we just heard from Dr. Domino, oxygen concentration plays an important role in atelectasis formation and the underlying physiological mechanism also applies to emergence and postoperative atelectasis. So, there are studies indicating that if you skip emergence preoxygenation, patients will develop less postoperative atelectasis, but we should not forget that 100% O2 is used here to increase patient safety. So, this is about an important tradeoff.

Regarding PEEP, I’m not aware of any other study investigating the role of PEEP during emergence.

Dr. BobbieJean Sweitzer: Dr. Domino, is this really a patient safety issue or are we just being ultraconservative in that we continue to place patients on 100% FiO2 before extubation even, say, we know their airways are easy to manage at the beginning of the case. They were totally easy mask, bag mask ventilation, they were totally easy laryngoscopy or supraglottic airways.

So, not saying that one maybe across the board we should avoid, but is it really a safety issue that we need to continue to use the 100% FiO2 in virtually 100% of patients before we extubate them?

Dr. Karen B. Domino: Well, I think the ones we’re really concerned about are trying to avoid hypoxemia in the case of the development of something like laryngospasm on emergence, upper airway obstruction that can occur after extubation or say if they had inadequate respiratory effort, although presumably one should be able to evaluate that prior to extubation.

And so, it’s a risk-benefit ratio that I think most anesthesiologists decide upon. There are patients I do extubate on a lower FiO2, but I’m very cautious in having adequate – and ensuring the patient’s adequately awake and responsive and won’t have an issue with laryngospasm, upper airway obstruction or inadequate respiratory effort.

I think if you wanted to apply this, maybe your idea as you mentioned, a laryngeomask airway, this would be healthy, non-obese patients having nonabdominal ambulatory surgery, that might be a category of patient that you wish to not place the patients on 100% FiO2 prior to extubation.

I think in most of the other sorts of patients, I still have been around long enough in anesthesiology to see some bad things happen, even to young healthy people. So, I would tend to be cautious in patients having more major abdominal surgery, higher-risk patients who have lung disease and patients who are morbidly obese.

Dr. Erland Östberg: I agree with Dr. Domino, but I – one of the findings also in this study is that this normal weight, healthy patient group, what the studies show is that they have a limited atelectasis formation despite being preoxygenated with 100% O2 during emergence.

That is, I think it’s conditional on PEEP used during anesthesia so that the lungs are open before or when the awakening starts. But after that, then this group, they tolerate a high oxygen concentration.

And I totally agree that the more complicated patient group with obese patients or patients undergoing or having other diseases and undergoing large surgery, that is a really tricky group because we both want them to have a large oxygen reserve when we extubate them and on the other hand they’re also probably more prone than the healthy ones to get postoperative pulmonary complications. So, we need to do more for that patient group, I think.

Dr. Karen B. Domino: I was just curious in that population of patients if you want to confer some patients some safety that had a higher FiO2, but not 100% and not 80%, what percent oxygen might you use? 60%, 50%? Do you have any research about that?

Dr. Erland Östberg: You mean for the healthy, normal-weight patient group?
Dr. BobbieJean Sweitzer: For any group of patients, is there possibly not one-size-fits-all or not binary? That either – because thank you for pointing out about the findings that the healthy patients that you studied here in spite of the 100% FiO₂, which they didn’t have really any significant problem, so then why not give that extra safety piece?

And the ones that maybe would benefit the most from not having 100% FiO₂ from a purely atelectatic perspective are the ones that are more likely to need that extra reserve of oxygen in case they get into trouble. But would there be any added benefit likely of, say, 80% FiO₂ or something less than 100% that would still give a relatively large FiO₂ reserve or oxygen capacity reserve, but also have a little bit with the atelectasis to balance the two?

Dr. Erland Östberg: Well, that has been studied by perhaps not during awakening, but after induction by Dr. Edmark in my group and his findings was that if you lowered the FiO₂ to, let’s say, 80%, you will still produce atelectasis, but it will take a little bit longer time than if you use 100% oxygen.

So, the conclusion from that study was that lowering the FiO₂ will still give you atelectasis but after some time and you will lose some of the safety time that is actually your intention with the preoxygenation. So, you put the patient a little bit at risk and you only delay the atelectasis formation.

You probably should go down to like 40% or closer to 30%. At 30% or 40% FiO₂, you have so much nitrogen in the alveoli, so they are more resistant to collapse and to absorption atelectasis.

Dr. BobbieJean Sweitzer: So, very interesting. So, you’d have to substantially reduce your amount of oxygen which would then may substantially reduce with the reserve that the patient would have in that (sounds like: intubation).

Dr. Erland Östberg: Yes.

Dr. BobbieJean Sweitzer: So, I think we’ve kind of decided that probably that is not the right tactic to go with. So, Dr. Östberg, should we be extubating patients who are at particularly high risk of postop atelectasis directly to noninvasive positive-pressure airway devices?

Dr. Erland Östberg: For some selected high-risk patients I would say yes, but it remains difficult to predict which patient would clearly benefit from such treatment and selecting the right patient is important since postoperative CPAP, for example, is resource intensive and in many hospitals requires submitting the patient to an intensive care unit.

And hopefully with more in future research investigating emerging from anesthesia, we might find ways to awaken our patients in a safe way without putting them at risk of postoperative pulmonary complications.

Dr. BobbieJean Sweitzer: So, I hope today’s discussion will interest many of our listeners and lead you to read this important article to learn more. Thank you so much, Drs. Östberg and Domino for discussing your work with us today. I wish you well as you continue your efforts to enhance the practice of anesthesiology and strive to improve the care of our patients.

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