Variable Effect of Positive End-expiratory Pressure on Oxygenation in Patients with Acute Respiratory Distress Syndrome

To the Editor—The recent article by Thille et al. and the accompanying editorial by Rouby discuss the effects of positive end-expiratory pressure (PEEP) on pulmonary recruitability in patients with adult respiratory distress syndrome (ARDS). Thille et al. found that alveolar recruitment was similar in pulmonary and extrapulmonary ARDS and concluded that PEEP levels should not be determined based on cause of ARDS. However, the type of ARDS could not be classified in 37% of the patients in their retrospective study, an important point that is further discussed in Rouby’s editorial. In the study by Thille et al., the response to PEEP was assessed by pressure-volume curves only, and the effect of PEEP on oxygenation is not reported.

More than 30 yr ago, we described the variable effect of PEEP on oxygenation in patients with ARDS. We found that both the short-term and the long-term effects of PEEP on oxygenation response in patients with sepsis were statistically smaller compared with that in patients without sepsis, and we concluded that ARDS associated with sepsis seems to be the result of a more severe pulmonary insult. In a subgroup of trauma patients, we found again that the improvement in oxygenation after the application of PEEP in patients who developed sepsis was significantly smaller than that of patients without sepsis and without lung contusion.

As imperfect as they are by today’s standards, these two very old studies do have relevance to the ongoing discussion about the effectiveness of pulmonary recruitment in ARDS because, in contrast to Thille et al.’s findings, they support the view that the effectiveness of PEEP does depend on the etiology of ARDS. It is unfortunate that for too many years we have not made much progress in better defining the various subgroups of ARDS. The clinician at the bedside is still left with one option only, namely, apply PEEP and assess its consequences. In fact, the response to PEEP may help in making the diagnosis.

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References


In Reply—I thank Dr. Perel for his interest in my editorial. He raises the question as to whether the presence of sepsis alters the effect of positive end-expiratory pressure (PEEP) on oxygenating capacity in patients with adult respiratory distress syndrome. Based on his own studies published in the late 1970s, he gives a positive answer and argues that such a result supports the concept that the cause of adult respiratory distress syndrome influences the effectiveness of PEEP and contradicts Thille et al.’s study. Going all the way through his belief, he proposes to use the effect of PEEP on oxygenating capacity as a diagnostic test to determine whether adult respiratory distress syndrome is septic.

The body of evidence supporting Dr. Perel’s statement is small. The retrospective study he refers to concerns a very heterogeneous population of 57 hypoxic patients (23 with multiple trauma, 21 with sepsis, 6 who underwent cardiopulmonary bypass, 4 with left heart failure, 2 with acid aspiration, and 1 with cerebral chord injury) and suggests that when severe hypoxemia is associated with or caused by sepsis, the increase in arterial oxygenation after the administration of a small PEEP (5.7 ± 1.2 mH2O) is less than that in the absence of sepsis. The heterogeneity of the patients studied (adult respiratory distress syndrome and cardiogenic pulmonary edema); the lack of any attempt made to optimize PEEP; and the absence of measurement of cardiac output, cardiac filling pressures, mixed venous oxygen saturation, pulmonary shunt, and alveolar recruitment preclude any analysis of the mechanisms involved in the observed difference. In addition, the second article, which is similar to the first, focuses on the 23 patients of the series, in whom lung injury was the result of traumatic lung contusion. It is well known that the initial phase of severe lung contusion can be characterized by severe hypoxemia, sometimes refractory to conventional means and requiring nonconventional mechanical ventilation. If the patient survives the initial phase, however, there is a rapid and spectacular improvement in arterial oxygenation related to blood clearance from the alveolar space allowing early extubation and spontaneous breathing. If, for extrapulmonary reasons, the patient cannot be extubated, then a second direct insult to the lung rapidly occurs, ventilator-associated pneumonia. In fact, the late deterioration reported by Perel et al. has nothing to do with “the cause of adult respiratory distress syndrome” but is related to the impossibility of weaning the patient from mechanical ventilation for extrapulmonary reasons.

Among the most convincing data pleading against the hypothesis that the septic lung recruits less than the nonseptic lung are those recently published byGattinoni himself, the initiator of the theory that patients with pulmonary adult respiratory distress syndrome caused by lung infection potentially have a much higher recruitable lung capacity than patients with extrapulmonary adult respiratory distress syndrome. Because of the lack of evidence supporting Dr. Perel’s assertions, his clinical recommendations should be taken with caution. Unless new convincing data are provided, the non-response to PEEP should not be interpreted by clinicians in charge of patients with adult respiratory distress syndrome as an indirect sign of lung injury associated with or caused by sepsis.

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In Reply.—We thank Dr. Perel for his interest in our article.1 He raises the issue of the influence of sepsis on positive end-expiratory pressure (PEEP) response in terms of oxygenation in patients with adult respiratory distress syndrome. Based on his own studies published in the late 1970s,2,3 he indicates that their result supports the concept that the cause of adult respiratory distress syndrome, or at least the presence of sepsis, influences the effectiveness of PEEP. He also suggests that the effect of PEEP on oxygenation may be part of a diagnostic test to determine whether adult respiratory distress syndrome is septic.

In our study, we did not directly address the points raised and try to reproduce these effects, for several reasons. First, Dr. Perel used small levels of PEEP with no standardization, making it difficult to reproduce these results. Second, we do not have systematic measurements of oxygenation at every level tested or assessment of the precise criteria for defining “sepsis” exactly at the time when the curves were performed. We do not think, however, that this is the right approach for at least two reasons. Based on the last 15 yr literature on PEEP, it has become clear that if PEEP is important, it is not because of its effects on oxygenation, but mainly because of its effects on lung recruitment and by making ventilation more homogeneously distributed.4 Arterial oxygenation has many drawbacks as a pure indicator of recruitment;5,6 and we have focused our more recent research on recruitment rather than oxygenation, mainly for this reason. The differences Dr. Perel described many years ago could be entirely explained by hemodynamic reasons independent of recruitment and could thus be misleading for clinicians. In addition, what we have shown is that there is no a priori difference in terms of PEEP-induced recruitment whatever the origin of adult respiratory distress syndrome.1 In other words, the clinician has to look for the individual effect of PEEP and not base the administered therapy on a priori criteria. We think this is an important message for today’s clinicians.

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In Reply.—On behalf of all the authors, I wish to thank Dr. Ortega and Ms. Hafez for this historical clarification regarding the design of the Ether Monument.

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To the Editor.—With great interest many anesthesia educators have read three manuscripts in previous issues of ANESTHESIOLOGY. Morgan, a well-known and respected researcher in simulation education, and her coauthors presented a thoughtful description of the use of simulation in the evaluation of teamwork in obstetrical practice.1 However, in light of their conclusions that the “study does not support the use of Human Factors Rating Scale for assessment of obstetrical teams” and recommended limited use of the Global Rating Scale, taken along with Murray and Enarson’s reflective editorial2 on the difficulties of teamwork and communication skills assessment, I fear that some anesthesia educators might be tempted to throw the newly born discipline of “simulation based assessment” out with the proverbial bathwater.

Morgan et al.’s investigation1 raises several issues that need to be addressed in light of our urgent need to develop authentic teaching and assessment of clinical competency in anesthesiology.3 The most pressing is our need for reliable and valid performance assessment tools used in anesthesia education, training, and practice. Morgan et al. found the Human Factors Rating Scale and Global Rating Scale assessment tools of limited reliability in the obstetrical setting; however, they do not further examine the sources of variance in the reliability other than from the raters themselves. Although the number of raters, the number of items, and the occasions of testing seem to be sufficient, we have no definitive analysis of this. Classic Test Theory and the use of interrater reliability and inter- and intraclass correlations for diagnosis of measurement error does not provide a view of the relative importance or interactions of these and other variances sources. Modern Test Theory, specifically Generalizability Theory, provides an analysis of multiple sources of variance and determination of optimal sampling not only for raters but also for subjects, items, and occasions of testing.3-6 In this investigation,1 the nonconcordance of the correlations of both Human Factors Rating Scale and Global Rating Scale suggest that something else is going on here. It could be the result of nonparallel scenarios, lack of rater training, or (more significantly), faulty construct validity of the Human Factors Rating Scale and Global Rating Scale for the anesthesia Crisis Resource Management trait. However, we do not know from this report.

In Reply.—We would like to thank Dr. Edler for her interest in our editorial.1 In an innovative study that measured teamwork during simulated obstetric emergencies, Morgan et al. found that the team scores were not reliable.2 The investigators attributed the limited reliability to the use of the Human Factors Rating Scale. Dr. Edler correctly indicates that the limited reliability could be the result of several factors and that a generalizability analysis that partitioned the variance associated with scoring method, raters, and scenario would help to clarify the findings. Regardless of the cause of the limited reliability, Morgan et al.’s main conclusion would still stand.

On reviewing the original development of the Human Factors Rating Scale7 and its 2000 revision, we still do not have formal psychometric analysis of its construct validity and factor status “due to limited sample size.”8 Although its authors claim that the items cluster around “team roles, authority/command structure, stress recognition and organizational climate,”9 these highly complex behaviors warrant more formal factor analysis before general use. We as anesthesiologists would not use a new clinical test without knowing the measure of its specificity and sensitivity; we should be equally rigorous with the degree of validity and reliability in high-stakes testing and use of resource-intensive instruction. Modern Test Theory offers many advantages necessary for the authentic assessment of complex cognitive, technical, and behaviors skills in simulation-based education and performance assessment.9

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In Reply—We would like to thank Dr. Edler for her interest in our article. First and foremost, in no way are we suggesting that simulation education be discarded, but, as Dr. Edler comments, there is a pressing need to ensure that we are assessing its impact using valid, reliable tools.

We also agree with Dr. Edler that generalizability is the way of the future and in fact is the analytic basis of our current ongoing study, designed to examine the psychometric properties of a newly developed obstetric team performance tool.

Our study was based on a sample size and using a design that would make the use of multifaceted generalizability analyses complicated at best. In fact, a generalizability analysis would likely be unstable because individuals were partially nested within team, and team was nested within scenario, and the number of actual performances was small for a generalizability analysis, which is why, ultimately, we adopted the analytic techniques we did for the study in question.

However, rater was fully crossed with all the dimensions that Dr. Elder described as other potential sources of variance, and it was the interrater reliability of the Human Factors Rating Scale that was a problem. Although we agree that other facets might add further error, there is no reason to believe that the interrater reliability would be better understood through the partitioning of other variances. With regard to the Human Factors Rating Scale, as Dr. Edler suggests, undoubtedly “something else is going on here.” However, based on our findings in the study, we have become substantially less interested in figuring out that “something else” than we might otherwise have been.

Instead, we decided that it will ultimately be more profitable to start from scratch, developing a tool that is generated out of the practice and experience of healthcare teams, rather than to spend our resources investigating a better understanding of what we think will ultimately prove to be the wrong tool.

Although we have independently come to the same opinions as Dr. Edler regarding the types of studies needed, based on our preliminary data, we decided that we will be looking to tools other than the Human Factors Rating Scale as the subject of these more elaborate generalizability analyses.

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ated by an oxidative stressor acting on the coronary microcirculation.\textsuperscript{6} A hyperoxia-induced decrease in coronary microcirculatory blood flow in patients with coronary artery stenosis can be detrimental.

To determine whether the routine use of high inspired oxygen concentration during the perioperative period alters the incidence of surgical site infection in a general surgical population, a double-blind, randomized controlled trial was conducted.\textsuperscript{7} The incidence of surgical site infection was significantly higher (25\%) in the group receiving inspired oxygen concentration of 80\% than in the group with inspired oxygen concentration of 35\% (11.3\%). This is further evidence that does not support the argument of Forkner et al.

Supplemental oxygen benefits patients who would otherwise suffer hypoxia while breathing room air. However, in this situation, supplemental oxygen would not induce hyperoxia. Forkner et al. made no distinction between supplemental oxygenation and the administration of high oxygen concentration.

The effect of hyperoxia-induced hypoxia on decreases in cerebral blood flow or other organ flow may not be great and is unlikely to be of clinical significance. However, the independent vasoconstrictive effect of hyperoxia is too great in magnitude to be ignored. One cannot say that hyperoxia is harmless.

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In Reply—We thank Dr. Her for his comments on our article.\textsuperscript{1} He notes that a previous human study by Floyd et al. demonstrated that the magnitude of the decrease in cerebral blood flow (CBF) induced by 100\% oxygen administration is more profound than that of the increase in arterial oxygen content,\textsuperscript{2} which seems to support the notion that hyperoxia can induce tissue hypoxia. This study, which used arterial spin labeled-perfusion magnetic resonance imaging, reported a 29-33\% decrease in CBF during 100\% oxygen breathing. If the 30\% reduction were accurate, then Dr. Her may have a point. However, this reduction in CBF is significantly greater than what has been observed in other studies, in which the reduction has been on the order of 5-15\%.\textsuperscript{3-5} Unfortunately the investigators in the Floyd et al. study made unwarranted assumptions. For instance, they assumed that T1 for blood was similar to that in blood and suggest that violations of this assumption would cause only a small error. This is clearly not the case and is the reason for the overestimation of changes in CBF found in their study.

In a recent article by Bulte et al.,\textsuperscript{6} in which 100\% oxygen reduced CBF less than 10\%, the changes in relaxation times of blood and tissue with increased $\text{Fio}_2$ are confounders of the arterial spin labeled technique, and that failure to accurately account for them when calculating perfusion will lead to gross overestimation of hyperoxia-induced blood flow changes.

We agree with Dr. Her that acute hypoxemia can be associated with markers of ischemia, such as impaired psychomotor performance, at least in the arterial $\text{Pco}_2$ range 20–25 mmHg.\textsuperscript{7} However, our original manuscript included data showing that during spontaneous breathing, the tendency of 100\% oxygen administration to cause hypoxemia is either very small or does not exist.\textsuperscript{1} Tissue $\text{Pao}_2$ regulates blood flow such that, although oxygen administration does induce vasoconstriction, there is a monotonically increasing relationship between arterial and tissue $\text{Pao}_2$.\textsuperscript{8-10} This has also been observed in the retina.\textsuperscript{11} In a pig study, the administration of 100\% oxygen reduced retinal blood flow by 62\% but increased perifoveolar and intervascular $\text{Pao}_2$.\textsuperscript{12} It is therefore unlikely that hyperoxia could contribute to retinal ischemia induced by an increase in intraocular pressure, and indeed there is direct evidence to the contrary.\textsuperscript{13}

Oxygen administration also reduces coronary blood flow; however, in the study cited by Dr. Her,\textsuperscript{14} there is no evidence that the reduced coronary blood flow induced either ischemia or myocardial hypoxia.

With regard to Dr. Her’s comment on oxygen and postoperative wound infections, evidence suggests an inverse relationship between tissue $\text{Pao}_2$ and infection rate,\textsuperscript{15} and the bulk of evidence supports the use of supplemental perioperative oxygen to reduce wound infection rate.\textsuperscript{16,17} The study by Pryor and colleagues cited by Dr. Her,\textsuperscript{18} which failed to demonstrate a beneficial effect, has been criticized on methodological grounds.\textsuperscript{19,20}

In summary, peripheral blood flow is regulated to maintain tissue oxygenation in the face of alterations in oxygen delivery. There is no evidence that the autoregulatory decrease in tissue blood flow during hypoxia induces tissue ischemia or hypoxia.

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To the Editor—We read the article by Mhyre and colleagues with interest.1 Although in the United Kingdom problems with tracheal intubation during obstetric general anesthesia remain the leading cause of death,2 there were no cases in their series from 1985 to 2003 suggesting that anesthesia providers in Michigan have been able to address this risk successfully. This is especially commendable as the rate of general anesthesia deaths, largely resulting from intubation problems or aspiration, was stable in the United States from 1979 to 1990.3

Many deaths in Mhyre et al.’s article were related to problems occurring some time after the induction of anesthesia. There are considerable differences between the United States and United Kingdom in anesthesia staffing both in the operating room and on the delivery suite, but the United Kingdom Confidential Enquiries into Maternal Deaths have repeatedly highlighted the vital role of the anesthesiologist in overall maternity care rather than just during surgery.2

However, we were surprised that there was no mention of regional anesthesia problems in the abstract or the accompanying editorial,4 as this was the primary cause of three of four anesthetic-related deaths during cesarean delivery. Of the eight patients who died from anesthesia-related causes, three were in the first or second trimester. The five patients in their third trimester all underwent cesarean delivery. One patient who had received a spinal anesthetic died 9 h postoperatively, related to systemic morphine treatment. The type of anesthetic is irrelevant to the death as the patient would likely have had patient-controlled analgesia even if she had had general anesthesia. Only one of the four women in whom the sequence of adverse events started during surgery had a primary general anesthetic, whereas three had regional anesthesia: a respiratory event at the end of surgery with a spinal, a cardiopulmonary arrest with an epidural test dose (presumably from spinal accidental placement), and a cardiac arrest with a spinal. Deaths from obstetric regional anesthesia are rare,5 and regional anesthesia is much safer than general anesthesia.6,7 However, this rarity means that the risk of cardiac arrest may be forgotten and need to be relearned.7

We need to recognize that cardiovascular collapse8 and unconsciousness from high block9 may occur suddenly at any stage during regional anesthesia and lead to morbidity or death unless managed promptly and effectively.3,9

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To the Editor.—In a recent editorial,1 Pinsky elaborated on the use of the plethysmographic recording obtained from a pulse oximeter in assessing volume responsiveness before instituting volume resuscitation. Pinsky noted that the plethysmographic signal is dependent on the density of tissue and pulsatile blood in the pathway of the infrared or red wavelengths and that this “. . . will be a function of both perfusion pressure and vasomotor tone. As upstream vasomotor tone increases, for example, pulse oximeter plethysmographic changes would decrease for the same pulse pressure, and vice versa with vasodilation.” The question is, however, whether it is the density or the variation in density that defines the plethysmographic variability.

I have for a couple of years routinely monitored pulse oximetry and plethysmography (Datex-GE, Helsinki, Finland) bilaterally in the lower extremities during abdominal aortic aneurysm repair and unilaterally in peripheral vascular reconstructive surgery. The plethysmographic signal is the first and failsafe herald of peripheral perfusion, and the lack of it likewise immediately warns of thromboembolic complications after declamping.

During one such procedure involving popliteal artery reconstruction under general anesthesia and spontaneous ventilation using a laryngeal mask, the plethysmographic signal after declamping is shown in figure 1, with the insert showing highly irregular beat-to-beat variation in amplitude.

The variation corresponds to variation in amplitude seen in the arterial pressure recording of the radial artery. The “silent” period at approximately 150 s represents manual compression of vascular graft. A perivascular Doppler flow probe was attached to the graft measuring a flow of 100 ml/min. The surgeon decided to assess the flow reserve of the receiving vascular bed, and papaverine 40 mg was injected intraproximally to the graft. The Doppler signal instantly increased to 200 ml/min, and the ensuing plethysmographic recording is shown in figure 2. The plethysmogram was all but abolished in response to the injection of papaverine. The arterial pressure remained largely unaffected by the peripheral vasodilation.

Initially, the response baffled me as I was expecting an increase with vasodilation, as stated by Pinsky. On second thought, the explanation became evident: the plethysmographic signal in Datex-GE pulse oximeters is highpass filtered, which resets the oscillations to vary between

The above letter was sent to the authors of the referenced report. The authors did not feel that a response was required.—James C. Eisenach, M.D., Editor-in-Chief.
To the Editor.—I read with interest Wrobel and Ziegeler’s article¹ that airway obstruction occurred during the use of a reusable laryngeal mask airway classic (LMA-Classic; The Laryngeal Mask Company, Henley-on-Thames, United Kingdom). In their report, a clear airway was obtained after insertion of a size 4 LMA-Classic and after inflation of the cuff with 20 ml air. During anesthesia, 10 ml air was added to the cuff to prevent airleak around the device, but the airway was obstructed. Close examination of the device after its removal showed that there was a cuff herniation that had not been detected at preuse checking. In a previous study,² which Wrobel and Ziegeler did not mention in their report, I showed that cuff herniation of the LMA-Classic may not be apparent if the cuff is inflated with the volume less than the recommended maximal volume (e.g., 30 ml for size 4) but may only become apparent when inflated with a volume of air 50% greater (45 ml). I also reported that if the cuff is inflated with smaller volume of air (e.g., 20 ml), there may be a dimple in the herniated part of the cuff, suggesting that there is a weakness of the cuff.² Wrobel and Ziegeler¹ stated that there was no problem at preuse checking, but the cuff was checked by inflating it with 20 ml air (Marc Wrobel, M.D., Department for Anesthesiology and Intensive Care Medicine, University of Saarland, Homberg/Saar, Germany; personal written communication, 2007). In figure 1 of their report,¹ cuff herniation was apparent when the cuff was inflated with 40 ml air (Marc Wrobel, M.D., Department for Anesthesiology and Intensive Care Medicine, University of Saarland, Homberg/Saar, Germany; personal written communication, 2007), and when the cuff was inflated with smaller volume of air (fig. 2 of their report), there was a dimple in the herniated part of the cuff.¹ These features are strikingly similar to results obtained in my previous article.² Therefore, if the integrity of the cuff had been checked by inflating the cuff with 45 ml air in their case, airway obstruction resulting from the damaged LMA-Classic might have been avoided.

Wrobel and Ziegeler suggested that the use of a silicone lubricant may damage the cuff.³ I pointed out that sterilization of the device in an autoclave with the cuff not tightly deflated or before any fluid has been infused into the cuff may also damage the cuff.² Any reusable device, particularly a well-used one, should undergo a proper preuse checking, and I suggest the following.

1. Before each use, the absence of cuff herniation (and any other deformities) should be confirmed by inflating the cuff with a volume of air 50% greater than the recommended maximal volume. This practice is now recommended by the manufacturer.
2. Before use, the absence of dimple in the cuff should be confirmed by inflating the cuff with 15-20 ml air.
3. After insertion of the LMA-Classic, the cuff should be inflated with approximately 15 ml air,³ and if airleak occurs around the cuff, air may be added until the cuff volume reaches the recommended maximal value.
4. If there is still airleak, the device should be removed, and a larger one should be used. The integrity of the removed device should be rechecked.

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To the Editor—Fiberoptic intubation is a very useful technique for patients whose tracheas are difficult to intubate using conventional methods. However, insertion of a fiberscope and insertion of an endotracheal tube over the fiberscope into the trachea are two major difficulties.1 We encountered an unusual difficulty during removal of the fiberscope after successful tracheal intubation. Our search revealed no such difficulty reported in the literature.

A 30-yr-old man with atlanto-axial dislocation came for trans-oral decompression and posterior fixation. An awake intubation was planned. After adequate oral and intravenous sedation, bilateral superior laryngeal nerve blocks, and topical anesthesia to the airway, a bite block was inserted.

Endotracheal tube (8.5, polyvinyl chloride) was loaded over the fiberscope (Fujinon F B 120-p, Fujinon Corporation, Saitoma, Japan). A long catheter (drug spray cannula) was inserted through forceps port of the fiberscope for the administration of local anesthesia in the event of inadequate anesthesia. This catheter comes with a fiberscope set.

The fiberscope and endotracheal tube were inserted through the mouth. Excellent local anesthesia was observed while introducing the fiberscope and the tube into the trachea, which was performed within 30 – 40 s. The patient remained comfortable during and after intubation of the endotracheal tube without any sign of distress. Administration of local anesthesia was not required. With successful intubation, we tried to remove the fiberscope. Initially we felt some resistance. After applying slight force, the fiberscope came out but the injection catheter remained inside the tube. We were unable to remove the catheter with moderate force. To determine the reason, we reinserted the fiberscope into the trachea over the catheter. We noticed that the catheter had gone beyond the tip of the endotracheal tube, making a U shape over the edge of it. We removed the tube along with the fiberscope and the catheter. The catheter was not used during the second attempt of awake fiberoptic intubation, which was accomplished without difficulty. Subsequent endoscopic examination of the distal trachea and major bronchi revealed normal anatomy.

We hypothesized that during advancement of the endotracheal tube over the fiberscope, the injecting catheter migrated beyond the tip of the fiberscope. With further advancement, it became U shaped over the edge of the tube, and one arm of it got trapped between the tube and the trachea, which caused it to be stalked within the tube (figure 1).

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