In Reply:

We thank Dr. Eisenkraft for taking the time to write regarding our recent article[1] and describe to us a detailed alternative scheme by which expiratory limb ventilation can be provided. The suggestion is valid and not the one that we thought of in this emergency. We were unaware of the Kummar *et al.* description, which does not explain how the Bain circuit was pressurized on his Aisys machine (GE Healthcare, Madison, WI). Dr. Eisenkraft's alternative demands mental preparation for such emergencies, just as we taught our option in previous simulations, and would require that the clinician recall the alternate common gas outlet circuitry immediately within a crisis situation. Although we admire his technically accurate methods of scavenging the volatile agent, we believe that such connections would not be available or clinically necessary in a brief emergency situation. From a technical perspective, we would like to raise three issues with his alternative.

1. *Room air entrainment*: what Dr. Eisenkraft describes is analogous to a Mapleson D (Bain) circuit, with the fresh anesthetic gas traveling down the inspiratory limb from the alternate common gas outlet to the Y-piece, but it differs on the distal expiratory limb end because the exhaled gas from the patient is scavenged to atmosphere upon reaching the self-inflating manual ventilation device (SIMVD) valve, and it does not mix within the SIMVD reservoir. When the reservoir is released after a manual inspiratory squeeze, it will entrain room air. When it is subsequently squeezed, the SIMVD reservoir would deliver room air retrograde to the patient, thereby diluting the exhaled and fresh anesthetic gas and oxygen mixture. Our alternative to connect the SIMVD to oxygen would theoretically deliver a higher concentration of oxygen, but it would not provide anesthetic gas.
2. *High fresh gas flow*: Dr. Eisenkraft's alternative is superior to ours in delivering anesthetic agent but would deliver enriched oxygen and maintain desired anesthetic concentration only if high fresh gas flow is provided *via* the alternate common gas outlet. We calculate a minimum fresh gas flow requirement of 18 l/min to prevent dilution by the SIMVD room air, given the example of 600 ml V_T delivered over 2 s. If oxygen was connected to his SIMVD, it would further enrich the oxygen concentration, but it would dilute the anesthetic agent. We agree that this connection is not necessary if his fresh gas flow is high enough.
3. *Rebreathing carbon dioxide*: analogous to the Bain system, and at high fresh gas flow, Dr. Eisenkraft's alternative ought to cause less rebreathing of carbon dioxide than our to-and-fro ventilation method.

In summary, we applaud this alternative suggestion as long as the clinician uses high fresh gas flow and desires the continuity of volatile anesthetic, but in the emergency situation we describe, we feel more secure in delivering higher oxygen concentrations from our SIMVD reservoir connected to auxiliary oxygen and do not see the need for scavenging arrangements. Our technique can be used on ANY anesthesia machine (without the alternate common gas outlet) and may require less technological understanding.

David M. Seif, M.D., Michael A. Olympio, M.D.* *Wake Forest School of Medicine, Winston-Salem, North Carolina. molympio@wakehealth.edu

Reference

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Cuffed and Uncuffed Tubes and the Geometric Correlation with Pediatric Airway

To the Editor:

We read with great interest the article by Litman[1] concerning the problems surrounding the choice of cuffed and uncuffed tracheal tubes in anesthesia and pediatric intensive care. Although the issue has been on debate for many years and now there is a general belief that cuffed tubes can also be safely used in children, I think it is important to make some reflections on the strict geometrical relationship between tracheal tubes and the anatomy of the cricoid and trachea. Both Litman and Weiss[2,3] have frequently reported and demonstrated that the cricoid lumen is not circular but rather of an ellipsoidal shape. By performing investigations with nuclear magnetic resonance, Litman has shown that the cricoid ring in its cross section is narrower than the anteroposterior section. This finding is, in our opinion, of considerable clinical importance and should not be overlooked. Considering that the orotracheal tubes have a perfectly circular shape, they are ill-adapted within an ellipsoidal structure. If we try to draw a circle inside an ellipse, imagining that the circle represents the tube and the ellipse is the cricoid, we can easily demonstrate that the tracheal tube, even if the proper size, can apply excessive pressure on cricoid structures along the minor axis of its elliptical shape. At the same time, the tube would not adhere well to the lateral areas of the cricoid corresponding to the major axis of the ellipse. This circumstance, in the presence of uncuffed tubes, creates the condition for an imperfect seal in the tube airway system with an increased risk of microinhalation, loss of gas, requiring repeated adjustments of mechanical ventilation parameters. Another risk present is the excessive movement of the tube and its tip with

consequent laryngotracheal mucosal microtrauma. On the contrary, the cuffed tubes can better adapt, thanks to the latest generation in cuff design, the ellipsoidal geometry airway and, contrary to what history has always claimed, they represent a considerable advantage in terms of efficacy and safety in pediatric patients as compared with the uncuffed tubes.

However, another important aspect should be taken into consideration regarding the variability of the geometry and morphology of the airways that is observed in neonates affected with a congenital disorder or after some operations where the geometric relationship between the endotracheal tube and airway may change dramatically, accentuating the problems described using uncuffed tubes. In his study, Fayoux[4] reported postnatal tracheal changes after *in utero* fetoscopic balloon tracheal occlusion in seven consecutive newborn infants with severe congenital diaphragmatic hernia. On careful examination of the bronchoscopic images reported by Fayoux in his article, a significant change is observed in the tracheal diameter indicating a more evident tendency to collapse during the expiratory phase, followed by a progressive dilatation of the trachea during the inspiratory phase, and a greater expansion of the upper part of the trachea compared with the lower similar to tracheomalacia. The geometric appearance taken, which one can observe, is exactly that of an ellipsoid. In this circumstance, or in clinical circumstances similar to the one just described, in a newborn inadequately adapted to the mechanical ventilator, the tracheal mucosa would produce repeated movements toward and away from the surface of a tube not fitted with a cuff causing micro-lesions in the mucosa and, moreover, no guarantee of an adequate seal for gas exchange. Even in these cases, the uncuffed tubes may not represent an advantage for children. Another disadvantage of uncuffed tracheal tubes is related to the geometric variation of the airways in relation to the progressive deepening of anesthesia over the course of its entire duration. In the initial stages of anesthesia, the tracheal tube may be adequate in size and seal without gas leakage. In the later stages, as a result of the deepening of the neuromuscular block and the incremental administration of anesthetic drugs and associated movements of the head and neck, the airway caliber is modified, and the presence of uncuffed tubes does not guarantee an adequate seal of the gas with consequent losses from the breathing circuit, inadequate $ETCO_2$ and capnography readings, and lung hypoventilation. With the cuffed tubes, this problem does not exist because the cuff ensures a greater seal and immobilization of the tube also with respect to the movements of the neck even when using tubes of underestimated size. In conclusion, we cannot fail to agree on the safety of using cuffed tubes in children. But at the same time, we should not underestimate the variations and changes in the geometry and anatomy of the airways, particularly in newborns, at various stages of pediatric development and in some comorbidities. Regarding technological innovations and new ideas for study, the analysis of the relationship between the cuffed/uncuffed tracheal tubes and laryngotracheal morphology with ultrasound-guided technique can be, in our opinion, a valuable additional tool for noninvasive real-time investigation especially in cases in which it is necessary to monitor the consequences of prolonged intubation.[5]

Dario Galante, M.D.,* Marco Caruselli, M.D. *University Hospital Ospedali Riuniti, Foggia, Italy. dario.galante@tin.it

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In Reply:

We thank Galante and Caruselli for their comments concerning our editorial[1] on the disadvantages of continuing to use uncuffed endotracheal tubes in the pediatric population. In addition to the reasons we discussed, Galante and Caruselli provide insights into the unique anatomical aspects of the pediatric trachea and thus, provide additional reasons to support the abandonment of uncuffed endotracheal tubes in pediatric patients. They also point out that the shape of the trachea may change during the course of a general anesthetic, and this change can only worsen the effects of an uncuffed endotracheal tube on the surface of the tracheal mucosa. However, we believe that the most important clinical consequences of the consistent use of cuffed endotracheal tubes will be evident in chronically intubated newborns, who seem to bear the brunt of ventilation-associated tracheal damage. An additional consideration for the smallest infants, who comprise the most likely population to require prolonged intubation, is the lack of availability of a size 2.5 cuffed tube. Endotracheal tubes with such small diameters are prone to plugging from secretions, and do not suction easily. In these infants, an uncuffed 3.0-sized tube may be the best available option for prolonged intubation in this vulnerable infant population.