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In Reply:—All the pregnant women included in our study were non-smokers and were referred to our hospital from different parts of the State of Tennessee. All patients spent 4–6 h in a smoke-free environment in our hospital before the blood samples were obtained.

Our own results from a previous study showed that carboxyhemoglobin levels of 3–6% decrease P_{50} by 2.5–4 mmHg.¹ We certainly agree that carboxyhemoglobin levels of about 3% is not the principal mechanism for a decrease in P_{50} in preeclamptic pregnant patients. We did conclude in our paper that elevation in CoHb levels was *partly responsible* for a decrease in P_{50} in preeclampsia. In addition to CoHb, certain hormones including prostaglandins may be responsible for a decrease in P_{50} seen in patients with preeclampsia. Several of these hormones are known to cause shifts in P_{50} .^{2,3}

Finally, we agree that 2,3-DPG levels play a role in oxygen dissociation from hemoglobin. However, measurement of 2,3-DPG levels is not necessary for P_{50} determinations. However, studies from various investigators show that 2,3-DPG levels are either unchanged or slightly elevated in pregnancy.⁴

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Polyvinylchloride Endotracheal Tubes are Hazardous for CO₂ Laser Surgery

To the Editor:—In their report on 523 patients who underwent general endotracheal anesthesia with plain polyvinylchloride (PVC) endotracheal tubes for operations using the CO₂ laser, Pashayan *et al.*¹ report one tube fire and near misses in 50% of their cases. The latter were cases where the laser had contacted PVC endotracheal tube but no combustion occurred. Their protocol of using a reduced inspired fraction of oxygen in helium is prudent, but the authors' adherence to the use of PVC endotracheal tubes is puzzling.

Pashayan *et al.* cite a study² indicating that PVC tubes are less flammable than red rubber tubes on contact with a propane torch. However, the opposite conclusion has been reported by Patel and Hicks³ using a CO₂ laser *in vitro* and by another study of the effects of tube fires caused by the laser on dog tracheas.⁴ Furthermore, PVC can produce copious toxic combustion products, such as HCl.⁵

The use of either a red rubber tube wrapped with appropriate metal foil tape or a metallic endotracheal tube would improve patient safety in these cases. Foil wrapping is inexpensive and, if done carefully, a relatively smooth exterior can be achieved. These tubes will allow greater laser energy and a higher Fi_{O_2} than that allowed in the protocol of Pashayan *et al.* to be employed. Their use should be considered mandatory in CO₂ laser endoscopic surgery.

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In Reply:—Dr. Sosis' disagreement with our study probably arises from a different interpretation of the literature cited in his letter. We do not believe the evidence supports his view that red rubber tubes wrapped in metallic tape or the use of metal tubes ensure "patient safety" more than the use of plain, unmarked, polyvinylchloride (PVC)

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tracheal tubes used with our helium protocol.¹ Patient safety during anesthesia for laser operations on the airway involves: 1) facilitating airway management in patients with known airway obstruction, which may be hampered by a bulky, stiff, metal or metal-wrapped red rubber tube; 2) insuring the patency and security of the airway, which is rel-

actively inaccessible to the anesthesiologist, and which may be compromised if a wrapped tube kinks, if tape loosens, or if a non-cuffed metal tube is used; 3) preventing misdirection of the laser beam onto normal tissues, which may occur when materials with a high specular reflectance, such as metal, are used; and, most importantly, 4) controlling the flammability of the anesthetic gas delivery system, which is not decreased by the use of red rubber because red rubber is more flammable than PVC.³

Existing confusion regarding the relative flammability of PVC and red rubber may stem from the 1981 article by Patel and Hicks,³ in which red rubber and PVC tubes were exposed to laser beams. Patel and Hicks concluded that red rubber tubes were less flammable, but they did not report the laser power density. The amount of heat delivered to a surface by a laser beam is dependent on the power density, which is a function of both wattage (which they reported) and spot size (which they did not report). Thus, we do not know if they controlled an important parameter of their study. Also, they did not control the oxidizing potential of the atmosphere surrounding the materials they tested. Instead of completely surrounding the tubes with the test mixture of gases, these investigators flushed the tracheal tubes with a mixture of 25% oxygen in nitrous oxide, which supports combustion similar to 100% oxygen.^{1,4} Because PVC is a thermoplastic material that can melt, when a laser beam hits PVC, a hole will result, which allows gas to escape. Red rubber tubes are not thermoplastic and ignite before melting. The PVC tubes in the Patel and Hicks report, therefore, would have leaked a highly oxidizing atmosphere at the point of laser contact, which supported combustion. The red rubber tubes would have contained the oxidizing gases and, since the laser hit the outside of the tubes, they were exposed to room air at the point of laser contact. The fact that any of Patel and Hicks red rubber tubes ignited confirms that they are more flammable than PVC, which does not ignite in room air.^{2,5} Finally, Patel and Hicks did not use plain PVC, as we recommend in the helium protocol,¹ but instead employed standard Portex tubes that contain radio-opaque material and lettering, which increases the flammability of PVC by lowering the temperature of spontaneous ignition.

A 1987 study of flammability characteristics of tracheal tube materials by Wolf and Simpson² used a method of testing, called the "oxygen index of flammability," that is accepted as a standard in the plastics industry. Their report clearly demonstrated that PVC is less flammable than either red rubber or silicone under standard conditions. Red rubber has the lowest oxygen index of flammability of the three materials and, thus, is the most likely to ignite in low concentrations of oxygen. Wolf and Simpson noted that PVC does melt, and stated that the amount of oxygen in a non-oxidizing diluent gas (*i.e.*, not nitrous oxide) must be limited in order to prevent fires. Also, other investigators, who studied laser-induced fires in dogs noted that red rubber tubes ignite prior to penetration and exposure to oxidizing gases.⁶

Dr. Sosis states that if a fire does occur, tracheal damage will be more severe with PVC than with red rubber. He cites the work of Ossoff *et al.*,⁷ in which airway fires were induced in dogs. Their report shows that, while tracheal intubation with PVC tubes was associated with more carbonaceous material in the trachea and bronchi, histologic examination showed similar acute injury in animals whose tracheas were intubated with either PVC or red rubber tubes. In fact, this same group reports a similar study in which "microscopic examination of the bronchi and lungs revealed severe injuries in dogs whose tracheas were intubated with the PVC and red rubber tubes."⁶ Based on this evidence, the appropriate conclusion is that damage to the airway can be severe if a fire occurs with either material.

Dr. Sosis' statement that we had 50% "near misses" in our series is incorrect. The term "near miss" is presumably derived from aviation accident analysis and implies that a disaster was near at hand. We had no disasters in 523 cases. We had one "near miss" during which the helium protocol was not followed, and fractional inspired oxygen con-

centration was increased above the 0.4 limit. The 50% statistic Sosis refers to no doubt relates to the incidence of laser beam contact with the tracheal tube, which leaves a mark on the tube; however, no fire occurred. In order to produce a fire in 60% helium/40% oxygen, a continuous laser beam of 10 watts and 0.8-mm spot size would have to be in contact with the PVC for more than 20 s.⁵ The helium protocol specifies that the laser be fired in a series of short, repeated bursts, each burst less than 10 s in duration. Therefore, we were never even close to tracheal tube ignition and our success in well over 523 cases demonstrates the wide margin of safety with this technique.

Finally, in our report on the helium protocol, we described a clinical technique, its limitations as well as its benefits, and reported our results. We did not specifically advise practitioners to follow our technique; we simply stated the facts and allowed readers their own interpretation. Critical reading and interpretation of the literature combined with clinical experience and consultation with the surgeon operating the laser should guide the anesthesiologist who must decide the method of management appropriate to each patient undergoing laser operations of the airway.

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