

The intracuff pressure increases are similar in the two types of cuffs, but the volume increase is greater in the high-residual-volume than in the low-residual-volume cuff.² The increase in cuff-to-tracheal-wall pressure is equal to the increase in intracuff pressure in the high-residual-volume cuff. In the low-residual-volume cuff, however, it is very difficult to know how much the cuff-to-tracheal wall pressure will increase from an increase in intracuff pressure. I agree with Carroll that with high-residual-volume cuffs the increase in cuff-to-tracheal wall pressure is probably the main reason why postoperative sore throats occur more frequently when air is used to inflate the cuff during nitrous oxide-oxygen anesthesia.³ I do not understand why the authors did not fill the cuffs with nitrous oxide, which is the logical consequence of the finding by Stanley.⁴ This would have eliminated the problem of increasing cuff-to-tracheal-wall pressure during the period of intubation. In Uppsala we have used this technique for three years, with satisfactory results.

We have studied the effects of high-residual-volume and low-residual-volume cuffs on mucociliary clearance of the trachea in animal experiments. There is no doubt that high-residual-volume cuffs inflated to 20 cm H₂O pressure seldom arrest the transportation of mucus after extubation. On the other hand, we have found that the low-residual-volume cuff inflated to a slight leak during ventilation causes considerable arrest of mucus transport in the trachea even after only half an hour of intubation. Our experimental findings (unpublished observations), in contrast to the suggestion of Loeser *et al.*, indicate that high-residual-volume cuffs should be employed in clinical practice provided the cuff is filled with the

same gas mixture as that used for anesthesia, and that the cuff pressure be measured.

Regarding the molded Lindholm tube, I regret to report that the tube used by Loeser *et al.* was obviously of the first experimental generation, which happened to have too short an intratracheal portion. In long-necked persons the cuff was therefore sometimes located in the larynx, which may explain why the incidence of severe sore throat was high with this model. Using molded Lindholm tubes with a longer intratracheal limb than the one used by Loeser *et al.* and low-residual-volume cuffs, we found an incidence of sore throat after intubation of 35 per cent, compared with 81 per cent following use of standard tubes (unpublished observations). Our mutual goal of developing tubes and techniques that are as non-injurious as possible would perhaps justify a multicenter investigation.

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In reply:—We appreciate the comments by Dr. Lindholm and find them quite rational. Indeed, a number of years ago we also believed that high-residual-volume, low-pressure cuffs should probably sustain greater volume increases than low-residual-volume, high-pressure cuffs when filled with air and exposed to nitrous oxide. We also suspected that the increase in cuff-to-tracheal-wall pressure secondary to nitrous oxide diffusion might be an important reason why postoperative sore throat occurred after endotracheal tube intubation. Unfortunately, our beliefs and suspicions, as well as those of Dr. Lindholm, did not stand up when subjected to careful scientific experiment. In a study in which 160 women undergoing similar oper-

ations had their tracheas intubated with five varieties of high-residual-volume, low-pressure air-filled cuffs and three varieties of similarly filled low-residual-volume, high-pressure cuffs (20 patients in each group) and were exposed to nitrous oxide and oxygen for similar intervals, there was no statistically significant correlation between initial cuff volume or pressure and changes in cuff volume or pressure during anesthesia, *i.e.*, changes in cuff volume and pressure were similar in low-residual-volume high-pressure cuffs and in high-residual-volume, low-pressure cuffs.¹ Some varieties of low-residual-volume, high-pressure cuffs, as well as some high-residual-volume, low-pressure cuffs, sustained larger increases

in cuff pressure and volume than others, but this was probably related to cuff design rather than initial cuff pressure or volume. In addition, there was a good deal of variation in volumes and pressure changes with the same cuff in different patients. The latter suggests that the relative size or position of the cuff in the trachea also plays an important part in cuff volume and pressure changes during anesthesia. Dr. Lindholm probably did not see the same kind of changes that we observed because he studied changes in air-filled cuffs during nitrous oxide anesthesia in only one variety of each type of cuff in a total of 18 patients.²

That the total increase in cuff-to-tracheal-wall pressure is probably *not* the main reason why postoperative sore throats occur when air is used to inflate low-residual-volume cuffs during nitrous oxide-oxygen anesthesia is confirmed by our recent study, quoted by Dr. Lindholm.³ In that study the highest incidence and most severe sore throats occurred in patients whose tracheas were intubated with endotracheal tubes with Kamen-Wilkinson foam-filled cuffs, in which the cuff catheter had no valve. Air in the foam-filled cuffs and nitrous oxide that diffused into the cuffs passed out of the catheters into the room. These cuffs sustained no cuff volume or pressure change during anesthesia, yet 65 per cent of patients whose tracheas were intubated with these tubes experienced postoperative sore throats. These data, when combined with our findings that postoperative sore throat is not correlated with changes in endotracheal tube cuff volume or pressure during anesthesia but is highly correlated with cuff-tracheal wall contact area,⁴ suggest that postoperative sore throat

can be minimized by employing endotracheal tube cuffs that have small areas of cuff-tracheal wall contact (cuffs with small width), irrespective of inflation cuff pressure or volume. They also indicate that while filling cuffs with a sample of the inspired mixture of gases will prevent cuff volume and pressure changes, it will not necessarily influence the incidence of postoperative sore throat. Recent findings (Stanley TH, Loeser EA, unpublished data) confirm that the incidence of postoperative sore throat after endotracheal intubation with high-residual-volume, low-pressure cuffs is not significantly changed whether cuffs are filled with a sample of the inspired mixture of gases, room air, or even physiologic saline solution.

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