

prolonged continuous monitoring of ventilated patients.

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## A New Low-pressure Cuff for Endotracheal Tubes

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Direct pressure from a distended balloon on the tracheal wall is the major etiologic factor in tracheal injury. The length of time the

pressure is maintained contributes to the severity of the injury.<sup>1-3</sup> To our knowledge, the safe pressure that the cuff may exert against the tracheal wall has not been determined, but it is likely to be a pressure that does not obliterate capillary blood flow (less than 20 mm Hg). The present study compares the pressures exerted on the tracheal wall by a newly designed endotracheal tube cuff and a standard commercial cuff.

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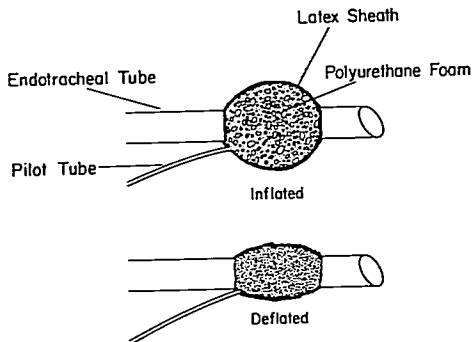


FIG. 1. Endotracheal tube with polyurethane cuff (inflated and deflated).

## METHOD AND MATERIALS

The cuff of a no. 34 red rubber endotracheal tube was removed and replaced with a polyurethane foam cuff 4 cm in diameter and sealed with a latex covering, so as to enclose the foam in an airtight sheath. The foam was bonded to the endotracheal tube with Pliobond cement. When suction was applied to the pilot tube, the cuff deflated sufficiently so that it could be passed through a glottis. A negative pressure of approximately 70 torr was used to reduce the foam to its completely collapsed state, which was 6 to 8 per cent of its normal inflated size. Releasing the negative pressure allowed the polyurethane foam to inflate and make contact with the tracheal wall (fig. 1). The pilot tube remained open to ambient air, and therefore, ambient pressure existed within the cuff.

A method of measuring lateral tracheal wall pressures was devised by placing an  $8 \times 20$  mm water-filled bladder between the cuff on the endotracheal tube and the tracheal wall. The bladder was connected to a low-pressure, low-volume strain gauge and the pilot tube was connected via one limb of a T piece to a high-pressure, low-volume strain gauge. Increments of air were injected into the cuff via the other limb of the T piece in the pilot tube. Pressures within the cuff and between the cuff and the tracheal wall (C-T) were measured on a Sanborn recorder. C-T pressures and the intracuff pressures exerted by polyurethane cuffed tubes and standard cuffed tubes on plastic, human cadaver, and sheep tracheas were measured. Cuffs were tested against respiratory cycling pressures (Bird respirator) as high as 40 cm  $H_2O$ , using a model lung preparation. Airway pressures were measured at the distal trachea.

## RESULTS

With the new cuff within a plastic trachea, pressures above 15 mm Hg were not recorded at C-T. Pressure within the foam cuff was always zero. When a fresh human cadaver trachea was tested, C-T pressure ranged from 2 to 7 mm, and there were no leaks until a respirator cycling pressure of 30 cm  $H_2O$  was exceeded. Again, pressure within the foam cuff was zero (fig. 2).

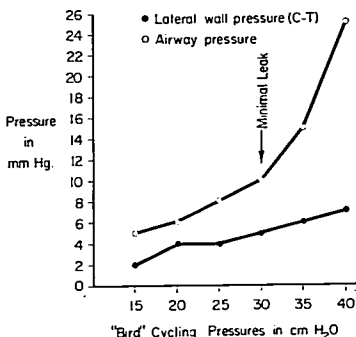


FIG. 2. C-T pressures and airway pressure exerted by the foam cuff in a human cadaver trachea  $2 \times 1.5$  cm at various respirator cycling pressures.

A standard no. 34 cuffed red rubber endotracheal tube was tested within the artificial trachea. When sufficient air had been injected to make an airtight seal, an intracuff pressure of 280 mm Hg and a C-T pressure of 110 mm

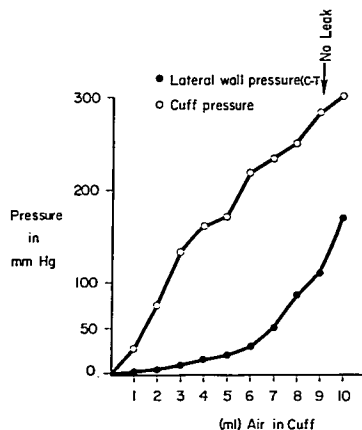


FIG. 3. Intracuff pressures and C-T pressures exerted by a standard cuffed endotracheal tube in a 2-cm plastic trachea with increasing increments of air in the cuff.

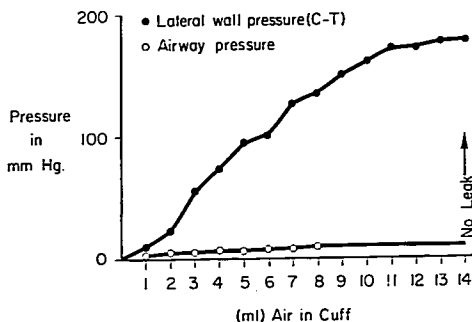


FIG. 4. C-T pressures and airway pressures exerted by a standard cuffed endotracheal tube in a human cadaver trachea with increasing increments of air in the cuff and a constant respirator cycling pressure of 15 cm H<sub>2</sub>O.

Hg were recorded (fig. 3). The tube was placed in a human cadaver trachea and respirator cycling pressures of 15 cm H<sub>2</sub>O were tested. A C-T pressure of 200 mm Hg was measured when enough air had been injected to prevent leakage (fig. 4). Similarly, the C-T pressures measured in an excised sheep

trachea were above 200 mm Hg, and intracuff pressures were above 400 mm Hg (fig. 5).

#### Discussion

Tracheal damage from prolonged inflation of cuffed endotracheal or tracheostomy tubes is a prevalent hazard. The tracheal cuffs in

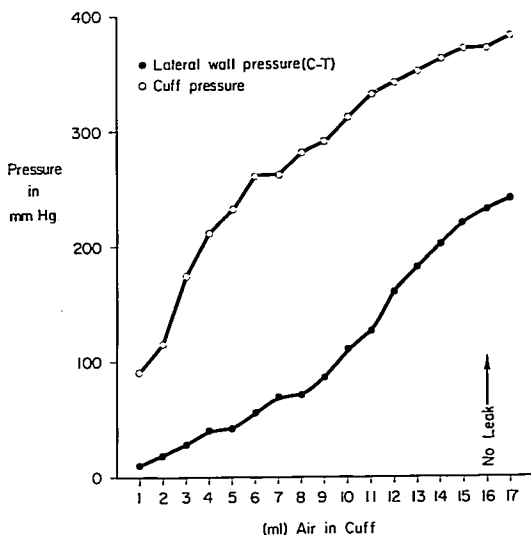


FIG. 5. C-T pressures and intracuff pressures exerted by a standard cuffed endotracheal tube in a 1.5-cm sheep's trachea with increasing increments of air in the cuff.

common use are not satisfactory for long-term application because of the excessively high pressures needed to produce an airtight seal. Our intracuff measurements are in agreement with those of Cooper *et al.*,<sup>4</sup> who showed that a standard cuffed endotracheal tube inflated to a point which prevented air leakage while a patient was ventilated at 20–25 cm H<sub>2</sub>O had intraluminal pressures of 180–250 mm Hg.

There is active interest in the design of less traumatic cuffs for endotracheal tubes.<sup>4-6</sup> Based on these preliminary tests, our low-pressure, latex-covered, polyurethane foam-filled cuff seems promising. The pressures exerted by this cuff against the tracheal wall are probably less than those necessary to produce tissue necrosis.

The firm bonding of the foam to the endotracheal tube precludes its slipping, and the possibility of its causing airway obstruction, therefore, is extremely unlikely. If the latex covering should rupture, withdrawal of the tube remains relatively atraumatic. Studies of tissue compatibility with polyurethane foam were not done. Currently we are determining optimum cuff dimensions for various sizes of endotracheal tubes and evaluating design changes.

This type of cuff may also be useful in the management of patients who need general anesthesia when they have full stomachs, since the cuff is rapidly self-inflating when the negative pressure is released.

# SUMMARY

A polyurethane foam-filled cuff has been designed for use on endotracheal or tracheostomy tubes. Pressure within the cuff was zero and pressures on the tracheal wall were lower than 15 mm Hg. Measurements of pressure with standard cuffed endotracheal tubes show intracuff values of 280 mm Hg and tracheal wall pressures as high as 200 mm Hg. Such pressures may explain the tracheal damage sometimes caused by prolonged endotracheal intubation.

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# Surgery

**PURCHASING DISPOSABLES** The foremost questions to consider when deciding between a disposable and a nondisposable item include: 1) Will the disposable product really reduce labor costs or will it just reduce labor? 2) Will the disposable product improve patient care? There are numerous cases where the reprocessing of quality items is preferable. 3) How are facilities and overhead affected? 4) How does capital equipment affect the hospital budget? 5) Is there a disposable product on the market that can be adapted efficiently to present procedures? Methodical examination of prepackaged trays which the hospital has been purchasing may reveal that some components included are no longer needed by the hospital due to changes in procedures or techniques. (Vallas, A. M.: *Standards for Judging Disposables Include Labor Savings, Improved Care, Mod. Hosp.* 114: 74 (March) 1970.)