Endotracheal Tube Lumen Compromise from Cuff Overinflation*

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A chest roentgenogram demonstrates lumen collapse as the cause of ventilatory obstruction in an intubated patient. This problem is not restricted to defective tubes but may be caused by overinflation of the cuff in normal tubes.

Despite the impressive record of endotracheal tubes as guardians of an unobstructed airway, human and mechanical failure causing these devices to become dangerous sites of obstruction in the upper airway continues to be reported.† This report and roentgenogram describe the potential hazard of endotracheal tube collapse from overinflation, a problem that has been reported in the past to result from defective manufacture.

**CASE REPORT**

A 12-year-old boy ingested 1,250 mg of amitriptyline plus 80 mg of thyroxine before notifying a relative of his suicide attempt. Paramedics arrived promptly and administered 10 ml of ipecac to an awake, alert child. However, the patient rapidly lost consciousness, and a 7.5-mm Portex Blue Line endotracheal tube was placed, and the cuff inflated with 8 ml of air. Positive pressure ventilation was applied during the trip to the hospital, but became increasingly difficult. Because of the apparent airway problem, a chest x-ray film (Fig 1) was taken on arrival at the emergency room. The collapse of the endotracheal tube was noted, and the cuff deflated to the point where it just occluded the tracheal lumen when 30 cm of positive pressure was applied. A repeat chest x-ray film (Fig 2) following reinflation of the cuff showed relief of the endotracheal collapse. Over the next 24 hours, the patient experienced sinus tachycardia and fever to 39° C, but awakened and was extubated uneventfully 24 hours later.

**DISCUSSION**

Prior reports of endotracheal tube collapse have emphasized its occurrence in defective endotracheal tubes, most commonly in armored tubes constructed by repeatedly dipping the structure in latex.5,6 Lumen collapse reported in a polyvinylchloride tube with a high-pressure cuff resulted in recall of a specific lot of tubes, which turned out to be defective.6 A recent report demonstrated collapse with overinflation in a specific brand of endotracheal tube, but likewise did not ex-

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FIGURE 1. Admission chest x-ray film shows endotracheal tube collapse at C7-T1 level.

FIGURE 2. Repeat chest x-ray film after deflation of cuff and reinflation to minimal occluding volume. Gastric tube for lavage also seen. This chest film shows lung fields to be less radiolucent than in Figure 1, most likely due to release of gas trapped behind intermittently obstructed tube.
greater than +20 cm H2O and is virtually rigid at pressures of +80 cm H2O. At such pressures, the exercised adult trachea becomes nondistensible with a volume of from 60 to 90 percent greater than its resting volume. Pressure-volume relationships in the in vivo trachea are unknown, but surrounding tissues may decrease distensibility. For intraluminal pressures greater than +80 cm H2O, a rigid cylinder becomes an acceptable tracheal model.

I reproduced the phenomenon noted in this case report with an unused 6.5-mm Portex Blue Line endotracheal tube warmed to 37° C. This tube has a relatively stiff, low compliance cuff. The tube was placed in a rigid cylinder of 13.8 mm to approximate the fully distented diameter of the normal 10- to 11-mm undistended tracheal diameter of a 12-year-old boy. Lumen collapse occurred consistently with infused volumes of between 8.0 and 8.5 ml of air. Pressure in the cuff was consistently greater than 450 mm Hg with this volume. At 20° C, collapse of the lumen could not be induced at any pressure.

Using the same model, 7.5-mm and 8.5-mm Portex Blue Line tubes collapsed at even lower cuff volumes. These volumes correlated with high intracuff pressures due to tight fits in the lumen of the tracheal model.

Attempts to reproduce the same phenomenon with high compliance cuffs were inconsistent. A 6.5-mm Shiley soft-cuff tube required 14.2 ml of air before collapse occurred on one attempt, but other balloons burst before lumen collapse on several inflations. A 7-mm Portex Hi-Lo tube also could be made to collapse but only with infused cuff volumes greater than 13 ml of air.

The 8.5-mm Blue Line tube could also be collapsed in an excised dog trachea. Because of the large size of the trachea, 23 mm in lateral diameter by 18 mm anteroposterior, 30 to 35 ml of air were required to cause lumen collapse, shown in a roentgenogram (Fig 3). When the tube diameter is substantially smaller than the tracheal size, as in this case, a large volume of air is required before the trachea approximates a rigid cylinder. Once that point is reached, however, pressure in the balloon rises rapidly, and collapse may ensue. Large tube size relative to tracheal size allows collapse at lower volumes, as demonstrated in the case report and model.

Endotracheal tube collapse due to overinflation is not restricted to defective tubes, but may occur when excessive intracuff pressures are achieved. Such pressures will not be achieved if care is taken to inflate the cuff only to prevent leakage of gas during positive pressure ventilation. An extremely tight-fitting endotracheal tube may reduce the volumes required to reach excessive pressures. Collapse may not be immediately evident on insertion of an endotracheal tube, since polyvinylchloride tubes soften with warming to 37° C. Patients who are anesthetized also run the risk of high cuff pressures and tube collapse due to diffusion of nitrous oxide into the cuff.

Current standards of endotracheal tube manufacture in the United States include a section, "Integrity of Lumen," that states:

The materials should be such as to allow construction of tracheal tubes with the thinnest possible walls whose lumen will not be compromised or collapse at the body temperature with the cuff normally inflated with the tracheal tube in the customary anatomical position of use.

This standard does not allow a margin of safety for cuff overinflation, which may readily occur in inexperienced hands.

This case and investigation demonstrate the need to inflate cuffs on the basis of leak occlusion and illustrate the hazard of inflating a tube with a fixed volume rather than on the basis of function. All personnel intubating or caring for intubated patients need to be aware of the potential dangers of cuff overinflation.

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