Anaesthesia Equipment

Cuff bulk of tracheal tubes in adolescence

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Purpose: To investigate cuff types for potential use in late childhood and early adolescence for appropriate fit.

Method: Formulae suggest the use of a tracheal tube having a 6.5 mm internal diameter at ages 8 to 10 years, so a model system was used to test the passage of cuffed and uncuffed tracheal tubes of 6.5 mm internal diameter through calibrated holes 8.1–16.6 mm diameter, in plastic plates.

Results: Uncuffed tracheal tubes passed through 9.0 mm diameter holes. "High pressure" cuffed tubes passed through 10.5 to 11.3 mm holes. "Low pressure" cuffed tubes passed through 12.3 to 16.4 mm.

Conclusion: Patients aged 8 to 10 yr have a limiting internal diameter at the cricoid of 8 to 10 mm. Their unstretched tracheal diameter below the cricoid is only about 11 mm. The actual outside diameters of "low pressure" cuffs chosen by commonly used formulae considerably exceed the limiting diameters of eight to ten year old patients, even considering recommended compensation factors. Analysis of background data indicates that these problems are especially aggravated at this age by non-linear growth of the cricoid.

Objectif: Examiner les types de manchettes pour les adapter à l'enfance avancée et au début de l'adolescence.

Méthodes: Les formules en usage proposent l'utilisation d'une

canule trachéale avec un diamètre interne de 6,5 chez les enfants de 8 et 10 ans. Un modèle a été utilisé pour tester le passage des canules endotrachéales de diamètre interne de 6,5 avec et sans manchette à travers des orifices calibrés dans des plaques de plastique de 8,1 à 16,6 mm de diamètre.

Résultats: Les canules sans manchette passent à travers les orifices 9,0 mm. Les canules à manchette à haute pression passent à travers les orifices de 10,5 à 11,3 mm. Les canules à manchette à basse pression passent à travers les orifices de 12,3 à 16,4 mm.

Conclusion: La partie la plus étroite de la trachée chez les enfants de 8 à 10 ans se situe au cricoïde et est de 8 à 10 mm. Sous le cricoïde non tendu le diamètre trachéal n'est que de 11 mm. Le diamètre externe des manchette à basse pression choisies selon les formules courantes dépasse les limites du diamètre des enfant de 8 à 10 ans, même si on tient compte des facteurs compensatoires. L'analyse des données de base montre que ces problèmes sont spécialement aggravés par la croissance non linéaire du cricoïde à cet âge.

Key words

ANAESTHESIA: paediatric;

EQUIPMENT: tubes, endotracheal, cuffs, endotracheal.

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The standard tracheal tube size designation is internal diameter (ID) in mm.¹ The actual outside tracheal tube diameter (AOD), which includes the deflated cuff, varies a great deal by cuff type and manufacturer. The ID, and the outside diameter (OD) printed on the shaft, give no indication of the cuff bulk determined AOD. This problem is especially important in children since their anatomy for establishing a tracheal tube seal is different than that of adults.

From infancy until adolescence, the location of the smallest airway diameter between the top of the glottis and the carina is at the unyielding cricoid, which is internally round.²⁻⁴ In that age range, a round uncuffed tube can provide a satisfactory seal if the AOD of the tube and the ID of the cricoid nearly match. Since the cricoid cartilage completely encircles the trachea, attempts to exceed its internal diameter during intubation will be traumatic. By adulthood, the narrowest aperture shifts to the vocal cords and a high volume cuff is appropriate. Since the opening between the cords is

not circular, unsealed passages at the cord level anterior and posterior to the tube would remain without using a cuff.

The practice of adding a cuff often begins at 6–10 yr despite the retention of the paediatric anatomical relationships throughout this age group.^{5–7} Motoyama⁸ advocates decreasing the tube size by at least 0.5 mm and Bennett and Bowyer⁹ by 1.0 mm from that listed by formula when adding a cuff. Wetzel and Maxwell¹⁰ suggest using low pressure, high compliance cuffs in small children. However, Steward¹¹ suggests that a cuff not be used on tube of ID <5.5 mm. The present study examined cuff types to determine which is likely to fit without excessive force if used during the transition from childhood to adolescence.

Method

A model system was used to provide an estimate of resistance when tubes were passed through holes of increasing diameter (8.1 to 16.6 mm) in 0.8 mm thick plastic plates (Berol RapiDesign San Fernando, CA). Commercially available 6.5 mm ID tubes from four manufacturers (Mallinckrodt, Portex, Rusch, and Sheridan) were evaluated. This ID corresponds to formula recommendations for ages 8–10 yr.^{5,12} These tubes included: (1) uncuffed, (2) "high pressure," and (3) "low pressure" cuffed tubes. To direct the tubes perpendicularly to the holed plates, the tubes were cut to their most distal segments, each weighing 4 g.

To determine a maximum standard force for inserting tubes, 19 anaesthetists who frequently intubate the tracheas of children were asked to press a tube on a scale with the maximum force they would use before trying a tube of the next smaller size. It varied greatly among anaesthetists surveyed, suggesting individual, arbitrary preference, and averaged 158 g (SEM = 20).

A string was threaded from a tube counterweight across a pulley and through each of these tubes segments under test to a 158 g weight which propelled the tube segments forward and determined the minimum hole diameter through which a tube segment could be driven within ten seconds. The resulting diameter was the uninflated AOD for each tube segment tested. If tubes did not pass through a given hole in ten seconds, the next larger hole was tried.

Results

Hole diameters that tubes passed are shown in the Table. Low and high pressure cuffs of a given ID vary in uninflated AOD both by manufacturer and model.

Discussion

Our results were compared with studies of the IDs of

TABLE Cuffed types and the smallest hole diameters in precision milled drawing plates through which tube segments could be driven by 158 grams within 10 seconds.

<i>Tube category</i>	<i>Tube vendor</i>	<i>mm hole passed</i>
Uncuffed	Sheridan	9.0
Uncuffed	Mallinckrodt	9.0
Uncuffed	Mallinckrodt RAE	9.0
Slim cuffed	Sheridan	10.5
Slim cuffed	Rusch	11.3
Slim cuffed	Mallinckrodt	11.3
Bulky cuffed	Mallinckrodt	12.3
Bulky cuffed	Mallinckrodt RAE	12.4
Bulky cuffed	Sheridan	13.4
Bulky cuffed	Portex	13.8
Bulky cuffed	Rusch	16.4

paediatric tracheas.^{13–18} If a bulky cuff is attached to a tube selected by the formulae, the uninflated tube AOD greatly exceeds the airway diameter. The uninflated, slim-cuffed tubes come closer to anatomical dimensions. Nixon¹⁸ plotted tracheal ID data previously appearing in the literature. The data points from Griscom¹⁷ come from levels below the cricoid. Of Nixon's sources, only Butz,¹³ Keep,¹⁴ and Slater¹⁵ directly measured the limiting diameter at the cricoid, and analysis of the data points derived from these three studies reveals the non-linear, reversed sigmoidal growth rate of the cricoid ID through childhood into adolescence. This indicates a temporary slowing of growth at the cricoid during the ages when cuffs are customarily first used. (Figure) It explains why the fit designated by linear formula should be more of a problem at this age rather than later in adolescence when the cricoid diameter resumes rapid growth.

Although a variety of tube shapes and cuff types has been tried, three general categories remain widely available: uncuffed, bulky-cuffed, and slim-cuffed tubes. In adults, problems with slim-cuffed tubes have been amply documented.^{19,20}

When using a slim-cuffed tube in late childhood or early adolescence, however, the volume and pressure of inflation, if any, required to achieve an adequate seal is small. The addition of an uninflated cuff by itself is often sufficient to provide an adequate seal. There is less need to use the voluminous cuff to fill an irregularly shaped lumen as in adults, because children's tracheas have a nearly round cross section.²¹ Since the difference between the tube body OD and the tracheal ID of a slim-cuffed tube is a few mm at most, it will pass into place through the cricoid ring more easily and with less trauma than would a bulky cuff. Any necessary few mm AOD expansion generally occurs with only partial expansion of the slim cuff, and it can do so at pressures

FIGURE Anatomy vs Results: The empty symbols designate the tracheal diameters of children. The empty round circles were obtained by CT tracheal scans, and the other empty symbols from physical measurements.¹³⁻¹⁷ The tube segments in this study are represented as solid symbols on or along side their minimum hole passage on the 10 yr line. Cuff types are designated as: solid circle = uncuffed, solid triangle = slim cuffed, solid square = bulky cuffed tubes. The reversed sigmoidal line represents the non-linear growth rate of the airway ID at the cricoid. This is derived by the non-linear, least square method by combining the data points from C. Nixon's¹⁸ three references¹³⁻¹⁵ which directly measured the limiting ID at the cricoid. (Airway measurement graph reproduced by permissions of C. Nixon¹⁸ and the American Roentgen Ray Society).

well below that of capillary filling. The space in adults between the tracheal ID and the tube shaft OD (limited by the cords) accommodating a bulky cuff is larger by a factor squared. This study suggests that a tube having a bulky "low pressure" cuff with shaft size selected by current formulae will have too large an AOD, and a likelihood of causing trauma on attempts at insertion. The bulk of the "low pressure" cuff can itself create a high pressure directed against the confining wall of the tracheal lumen. If a cuff is used at all for this age group, the use of a slim "high pressure" cuff on a tube picked by formulae should be much less traumatic. In our opinion, for this targeted age, a cuff of minimum bulk inflated to seal at low volume should be preferred, rather than contraindicated.

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