Uncuffed versus Cuffed Endotracheal Tubes

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During the last five decades, uncuffed tracheal tubes were recommended for routine use in children aged below 8 years. Cuffed tracheal tubes in patients younger than 8 years of age were only exceptionally used for special indications. In the last 10 years a change in clinical practice and in the design of cuffed pediatric tracheal tubes occurred. This lecture aims to demonstrate problems and developments with regard to uncuffed and cuffed tracheal tubes, to explain differences between airway sealing using an uncuffed or cuffed tracheal tube and to give recommendations for the use of uncuffed and cuffed tracheal tubes in children.

Uncuffed tracheal tubes in children

Only uncuffed tubes should be used in children below the age of 8-10 years (1). This is the traditional teaching in pediatric anesthesia and intensive care. The argument to use only uncuffed tracheal tubes in this group of children is based on the finding that the narrowest part of the airway is the cricoid. Introducing an uncuffed tracheal tube that just fits and seals within the cricoid makes a cuff unnecessary (2). However, a single tracheal tube rarely fulfils these two conditions, as demonstrated by the development of numberless formulas and rules for uncuffed tracheal tube size selection (3) and the high tube exchange rates up to 28% (4, 5). When a correctly sized tube cannot be found, anesthesiologists have the dilemma to accept an uncuffed tube with a large air leak or to insert an oversized tracheal tube.
Oversized uncuffed tracheal tubes are well known as the main cause of laryngeal injury due to tracheal intubation (6-8). Large air leakage with uncuffed tracheal tubes results in unreliable ventilation and oxygenation, imprecise capnography and lung function testing, high gas flow consumption, environmental pollution of anesthetic gases as well as pulmonary aspiration (9, 10). Nevertheless, in the last 50 years anesthetists have accepted and taught these shortcomings sometimes making pediatric airway management difficult (9).

Cuffed tracheal tubes in children

Cuffed tracheal tubes were only exceptionally used in patients younger than 8 - 10 years of age. They were accepted in some pediatric critical care units for younger children not tolerating changes in tidal volume or airway pressure, caused by changing air leak with level of sedation and muscle paralysis or with head position (9). Although the problems associated with uncuffed tracheal tubes can easily overcome by the use of a cuffed tracheal tube there are several concerns for their routine use in younger children. They include the higher costs, the smaller internal diameters selected, the potential for cuff hyperinflation, the risk of laryngeal damage and post-intubation stridor and the many shortcomings in the design of cuffed pediatric tracheal tubes (10-11).
In the meantime, there is evidence that smaller diameters are not a real problem (12) and that the higher costs associated with cuffed tubes are outweighed by savings in exchanged tracheal tubes, anesthetic gases, oxygen and air consumption as well as reduced indirect costs due to low (no) environmental pollution and low

tracheal tube exchange rate (5, 13). Cuff hyperinflation is not a pediatric problem but a problem of absent cuff pressure monitoring in many anesthesia and intensive care departments (14). To date, simple cuff pressure release valve, cuff manometers and cuff pressure regulators are available for clinical use (15). Large single centre experience and clinical studies have not confirmed a higher incidence of laryngeal trauma or post-intubation stridor caused by cuffed pediatric tracheal tubes in pediatric anesthesia or pediatric intensive care, (5, 16-20) as long as correctly sized tracheal tubes and cuff pressure monitoring is used.

A real problem associated with cuffed pediatric tracheal tubes is the several shortcomings in their design potentially leading to airway trauma. They include inappropriate diameter of the cuff, too long cuffs, wrong cuff position, absence or wrongly positioned intubation depth marks, considerable differences in outer diameters in tubes with identically sized internal diameter, lack of cuff pressure monitoring equipment and absence of confirmed recommendations for pediatric cuffed tracheal tube size selection (21-27). In 2003, none of the investigated pediatric tracheal tube cuff diameters up to tube size internal diameter (ID) 4.5 mm fulfilled the requirement of a high volume - low pressure cuff. Some of the tube cuffs were too long, either leading to an endobronchial tube tip positioning, if the cuff is placed below the larynx, or resulting in an intralaryngeal cuff position when placed according to an age related tube insertion depth formula. Particularly in preformed oral tracheal tubes, where the tube cuff becomes automatically placed according to the tracheal tube's bend, many of the tracheal tubes would result in an intralaryngeal cuff position.

In 2004 a new cuffed pediatric tracheal tube became available with improved design and excellent sealing properties (28, 29). As an innovation, tracheal tube cuffs made from polyurethane allow the construction of a very short HVLP cuff with improved sealing characteristics (30, 31). This tracheal tube was successfully tested in pediatric patients from birth up to adolescence in several clinical settings (28, 29, 31-35). In the preformed oral version, designed by the manufacturer himself, the cuffs are still too high (36). Based on preliminary investigations and requirements for safe use of cuffed tracheal tubes in children, further improvements of the new tube design and the accessory equipment are still needed (9).

Future developments in cuffed pediatric tracheal tubes includes a narrowed tube tip design for increased space around the cuffed tracheal tube within the cricoid lumen (10) and automatic cuff pressure control mechanism such as cuff auto-inflation or integrated pressure release valve (10, 37).

Airway sealing in children by tracheal tubes

Newer investigations in children revealed, that the cricoid lumen is not a circular but mostly an ellipsoid structure (38). If a round uncuffed tracheal tube is inserted into the noncircular lumen to sufficiently seal the airway, considerable pressure on the latero-posterior walls of the cricoid occurs. The air leak at an inspiratory pressure of 20-25 cm H_2O, thought to prevent excessive mucosal pressure may arise only from the anterior part of the cricoid lumen. This is called "cricoidal sealing". With cricoidal sealing the pressure exerted on some parts of the cricoid mucosa is not known and may be excessive in spite of an air leak. This is in contrast to "tracheal sealing"

where a cuffed tracheal tube with a smaller diameter is selected which does not wedge within the susceptible cricoid and the airway is sealed within the trachea using a cuff (39). In contrast to cricoidal sealing, tracheal sealing with a high-volume low-pressure (HVLP) cuff allows to estimate and adjust precisely the pressure exerted by the cuff on the tracheal mucosa.

Tracheal sealing in 500 children aged from birth to 16 years using a new cuffed pediatric tracheal tube with HVLP cuff revealed an air leak with the cuff not inflated at <10 cm H_2O inspiratory pressure in about 80% of children (29). In 95% of these patients the trachea was completely sealed with a cuff pressure of less than 15 cm H_2O (mean cuff pressure 9.7 cm H_2O). The tube exchange rate was only 1.6%.

Today, there is only limited evidence comparing "cricoidal sealing" with "tracheal sealing" in pediatric intubation. Clinical studies have demonstrated similar rates for post-extubation stridor, but lower or even zero tube exchange rates and a sealed airway without the use of an oversized tracheal tube (5, 16-20, 29, 36). In future time, endoscopic trials are required to investigate pediatric airway trauma caused by "cricoidal sealing" and "tracheal sealing".

Recommendations

Cuffed tracheal tubes in smaller children are increasingly used because of the high chance to insert a correctly sized tracheal tube at the first intubation attempt and to create an effectively sealed airway without the use of an oversized tracheal tube (39).

In several anesthesia institutions cuffed tracheal tubes are successfully routinely used from size internal diameter 4.0 mm and cuffed tracheal tubes are to prefer in patients at risk for pulmonary aspiration, with low lung compliance (including laparoscopic and thoracoscopic procedures, and surgery on cardio-pulmonary bypass) and in whom precise ventilation and/or CO_2 control is important (40). In patients with severe burns, uncuffed tracheal tubes should not be used any longer (41).

The American Heart Association (AHA) and the International Liaison Committee on Resuscitation (ILCOR) stated in their 2005 guidelines for pediatric resuscitation, that the use of cuffed tracheal tubes in infants and children is now an accepted alternative to uncuffed tracheal tubes and that they have to be preferred over uncuffed tracheal tubes under certain conditions (42, 43). The reason for this change was that evidence has accumulated that cuffed tubes can be used safely in children (42).

Based on current scientific data cuffed tubes can be safely used in infants and young children provided that a correctly sized tracheal tube (sufficient air leak), continuous cuff pressure control and adequately designed tracheal tubes are used.

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