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Original Research

Uncuffed Endotracheal Tubes: Not Appropriate for Pediatric Critical Care Transport

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ABSTRACT

Objective: The effect of using uncuffed endotracheal tubes in children during interfacility critical care transport has not yet been assessed. We hypothesized that many children with uncuffed endotracheal tubes experience complications leading to replacement with a cuffed tube after arrival at a tertiary pediatric care facility.
Methods: We conducted a retrospective case review of all intubated patients transported by our dedicated pediatric critical care transport team to our pediatric intensive care unit over a 3-year period. The incidence of urgent reintubation was studied.
Results: A total of 213 children were referred for transport with an endotracheal tube in place, with 55 of those with an uncuffed endotracheal tube (25.8% of all intubated patients). Of those with uncuffed tubes, 24 patients needed their tubes replaced on an urgent basis by the medical team because of issues with ineffective ventilation (43.6% of patients with uncuffed tubes or 11.3% of all intubated patients). No cuffed tubes required replacement.
Conclusion: Placing an uncuffed endotracheal tube in the critically ill child who is referred to tertiary pediatric care results in a significant number of these patients undergoing a repeat laryngoscopy, with all associated risks, to replace the uncuffed tube with a cuffed tube.

The history of the use of the uncuffed endotracheal tube is remarkable in that it includes nearly a century of assumptions, questionable premises, and technological limitations, passed along from one generation of medical providers to the next. In 2011, Taylor et al wrote "The shortcomings of uncuffed endotracheal tubes have been accepted and tolerated for 50 years."[1] Historically, medical providers trained throughout the 20th century held a preference for uncuffed tubes based on the idea that the pediatric upper airway itself is conical (in contrast to the adult upper airway, which is cylindrical) with the narrowest part of the pediatric airway at the cricoid ring. According to Tobias,[2] these teachings are based on a 1951 manuscript by Eckenhoff published in *Anesthesiology*. Eckenhoff referenced the work of Bayeux who, in 1897, made plaster casts of the airways of 15 deceased children. Based on the shape of the casts produced and the finding that the cricoid ring was the narrowest portion of the airway in all 15 cadaveric children, it was surmised that the pediatric upper airway is conical. Tobias[2] points out the weaknesses in the Bayeux study because it was limited in size with wide variation in age of the subjects and the process of pouring plaster into the airway of a deceased individual who lacks muscle tone in the distensible part of the upper airway likely resulted in a distorted cast, leading to an erroneous assumption concerning its purported conical shape. Tobias[2] states that even in the oldest subject, a 14-year-old, the conical cast was produced. In addition, both Bayeux and Eckenhoff themselves cautioned that because the study was performed on cadavers, the findings may not be applicable to living subjects. Despite such caveats, the assumption that the upper airway in children age 8 years and younger is conical with the cricoid ring being the narrowest portion has persisted for decades.[2,3] Recent studies of the pediatric airway have been performed using bronchoscopy, computed tomographic imaging, and magnetic resonance imaging in a significant number of living

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subjects, with various degrees of sedation and neuromuscular blockade. These studies questioned the beliefs that the pediatric airway is conical and that the airway changes shape from conical to cylindrical during maturation into adulthood, finding that an increase in all airway dimension ratios is, in fact, linear during maturation.[2-4] These studies also revealed a previously unknown characteristic—the geometry of a cross section of the airway was assumed to be circular but was found to actually be slightly elliptical, with the lateral dimension narrower than the anterior/posterior dimension.[1,2,5] Holzki et al[6] argue that in vivo studies tend not to show a funnel-shaped airway, but they do not consider motion of the upper airway in the living subject undergoing examination, whereas in vitro studies tend to support a funnel-shaped airway.

Debunking Arguments Against Cuffed Tubes

Cuffed endotracheal tubes are increasingly used in children in the United States, with 85% of Society of Pediatric Anesthesia member survey respondents reporting they use cuffed tubes in children older than 2 years at least 50% of the time.[7] However, some medical providers remain unaware or unconvinced of the safety and efficacy of the use of cuffed endotracheal tubes in the pediatric patient.[3,8,9] An argument historically presented against the use of cuffed tubes is that their use may result in tracheal injury such as subglottic stenosis. Studies have clearly shown that there is no increase in tracheal injury with the use of cuffed tubes.[3,7,8,10,11] With cuffed endotracheal tubes in operating room patients, Chambers et al[10] reported a decrease in adverse events such as sore throat and hoarseness, possibly as a result of the higher number of laryngoscopies needed to place and replace uncuffed endotracheal tubes. Sore throat in those patients with cuffed endotracheal tubes correlated with the use of excessive cuff pressures.[10]

A classic argument against cuffed tubes is that a smaller tube size is required to accommodate the cuff and causes increased ventilatory resistance. Although there are clear benefits to the appropriate use of the largest internal diameter tracheal tube in terms of maximizing ventilation, this argument has its origin with the use of antiquated rubber tubes, at a time when the primary indication for endotracheal intubation in children was in breathing patients in the operating room.[5] With advanced tube design and the use of modern ventilators, the increased resistance of the smaller internal diameter tube is easily overcome. In fact, Chambers et al[10] reported improved ventilation and a lower rate of complications with cuffed endotracheal tubes versus uncuffed endotracheal tubes in their study of patients under general anesthesia for elective surgical procedures. Cuffed endotracheal tubes may be a source of tracheal injury if the cuff is inflated to excessive pressures (>25 cm H_2O), but there are simple techniques to monitor and adjust cuff pressure.

Early versions of cuffed endotracheal tubes in pediatric sizes were discovered to have a proximal placement of the cuff that increased the rate of dislodgment and were met with resistance by some anesthesia providers. That design flaw has been eliminated, and high-volume/low-pressure cuffs are now the standard.[4,7,12] Advancements in the technology of endotracheal tube production have allowed cuffed tubes to be safe and effective in even the smallest patients.[4,5]

Arguments Against Uncuffed Tubes

Uncuffed endotracheal tubes have limitations, including an increased rate of replacement to adjust to correct sizing and increased leakage compared with cuffed tracheal tubes.[7,10,12] In the child with severe respiratory illness or lung injury such as thermal inhalation or near drowning that may require high ventilatory pressures, leaks from an uncuffed tube may force reintubation to place a cuffed tube, subjecting the child to additional intubation procedures.[12,13] The "gold standard" for verification of correct endotracheal tube placement is end-tidal carbon dioxide ($ETCO_2$) monitoring via digital capnography. The $ETCO_2$ readings may be unreliable with an uncuffed tube with a large leak.[10] An uncuffed endotracheal tube may allow the airway to be inadequately protected against aspiration of material into the trachea.

First Pass

In critically ill patient with acute respiratory compromise, the literature reports a relationship between failing to successfully pass an endotracheal tube on the first attempt and the increased likelihood of ensuing cardiac arrest.[14] Subjecting a child to multiple intubation attempts with uncuffed endotracheal tubes to find one that functions may begin the same chain of events that causes cardiac arrest in the missed intubation attempt scenario. Regardless, it subjects the child to multiple laryngoscopies and the placement of multiple tubes through the glottis. Each progressive visualization of the airway is typically met with an increasing level of difficulty for success.[15] One intubation attempt, with successful passage of a cuffed endotracheal tube and with minimal disturbance of the airway mucosa and no need to repeat the procedure, should be the goal when intubating a pediatric patient.

Our Pediatric Critical Care Transport–based Study

There were no studies found that addressed the use of cuffed versus uncuffed endotracheal tubes in the pediatric critical care transport patient. To address this gap, this study sought to show that a potential decrease in morbidity and mortality may be realized by the use of only cuffed endotracheal tubes in the pediatric critical care transport patient. The purpose of this study was to determine if the use of uncuffed endotracheal tubes during interfacility critical care transport by a trained pediatric specialty transport team leads to an increased incidence of urgent replacement with a cuffed endotracheal tube.

Methods

Study Design

Institutional review board (IRB) approval was sought, and we were granted approval via expedited review for this retrospective study. The rate of additional laryngoscopies with reintubation in the intensive care unit after patient arrival on the unit from the transport team was the key indicator studied.

Study Population

The study population consisted of all patients transported by our dedicated pediatric critical care transport team (patient age range: 2 months-14 years) who had an endotracheal tube placed before transport. Chart review was performed for calendar years 2014 through 2016, and the population size (N) was 213 patients. The sample of patients with an uncuffed endotracheal tube in transport ($n_1 = 55$) was compared with the sample of patients with a cuffed endotracheal tube in transport ($n_2 = 158$). Follow-up data were later added for 2017 with IRB approval.

Hypothesis

Our null hypothesis is that the use of uncuffed endotracheal tubes in pediatric critical care transport patients does not predict the rate of reintubation for tube replacement.

Exclusion Criteria

Neonatal intensive care unit patients at our facility, treated under separate protocols, routinely receive uncuffed endotracheal tubes and were excluded. Patients with inadvertent extubation before or during transport or with airway trauma or inadequate sedation were considered for exclusion; however, no patients met these exclusions in our population sample. Multiple intubation attempts are associated with injury and inflammation to the airway and were an exclusion criterion when attempts exceeded 3; however, no patients had documentation available to indicate the number of attempts before the arrival of the transport team.

Results

The decision to replace an uncuffed endotracheal tube with a cuffed tube was based on clinical evaluation by the pediatric intensive care unit attending physician or fellow and occurred bedside in 17 cases and via medical command direction to the transport team clinicians or referring facility medical staff in 7 cases. We found that of the 213 intubated patients, 55 (25.8%) had an uncuffed endotracheal tube placed. There were 24 patients with uncuffed tubes who had those tubes replaced with cuffed tubes (43.6% of patients with uncuffed tubes or 11.3% of all patients). One hundred thirty (61%) patients originated in a referring hospital's emergency department. Twenty-two (40%) of the 55 patients with uncuffed tubes originated at a single health system's facility, indicating a prime location for outreach. The most common uncuffed endotracheal tube that was replaced was size 3.5 with 9 (37.5%) replacements followed by size 4.0 with 6 (25%) replacements. The median time to replacement of uncuffed tubes was 3.78 hours after arrival. The shortest replacement time after intensive care unit arrival was 29 minutes, and the longest replacement time was 29.7 hours; each had difficulty documented with adequate ventilation prompting the replacement. For those 9 uncuffed tubes replaced urgently (supported by provider notes that ventilation was critically inadequate with the uncuffed endotracheal tube), the mean time to replacement was 2.7 hours. Notably, we found no cases in which a cuffed endotracheal tube needed to be replaced because of the inability to effectively manage ventilation.

Twenty-three patients were female, and 32 were male. Eighteen (75%) of the patients who had uncuffed tubes replaced were male. Twenty-two (40%) patients who had uncuffed tubes had a chief complaint of, or related to, a respiratory condition, and, of those 22, 12 (54%) of those with uncuffed tubes had their tubes replaced. In 2014, there were 10 patients with uncuffed endotracheal tubes replaced, 9 in 2015, 5 in 2016, and 7 in 2017 (supplemental data added with IRB approval). Interestingly, 10.9% of patients presenting with uncuffed endotracheal tubes ultimately died, whereas 8.9% of those presenting with cuffed endotracheal tubes died.

Discussion

It is the policy at our hospital to select a cuffed endotracheal tube as the primary choice when intubating children (except for neonatal intensive care unit patients). The literature shows that there are no significant contraindications to the use of cuffed endotracheal tubes in the pediatric patient and that there are benefits to their use, particularly in the critically ill respiratory patient when the ability to protect the airway and provide maximized tidal volumes or pressure or both may be required. Indeed, we found that a significant number of respiratory patients needed urgent replacement of their uncuffed endotracheal tube with a cuffed tube for the medical team to provide adequate ventilatory support. The ability to verify proper endotracheal tube placement in the transport or emergency medical services environment may be confounded by noise, poor lighting, or other distracting environmental factors. In that environment, the use of $ETCO_2$ capnography is vital and is more reliable with a cuffed endotracheal tube.

Our finding of 100% of cuffed tubes remaining in place with 56.4% of uncuffed tubes remaining in place throughout the intubated care interval is similar to the study of Weiss et al[11] of operating room patients in whom 97.9% of cuffed tubes remained in place and 69.5% of uncuffed tubes remained. In the challenging settings of interfacility critical care transport and prehospital emergency transport (where the same constraints on resources exist), the ability to place a correctly functioning endotracheal tube approaching 100% of the time by simply using a cuffed tube is significant.[11]

Both in vitro and in vivo studies support the cricoid as the narrowest (or functionally narrowest) region in the pediatric airway.[2,6] For the critical care transport team, who seeks to optimize ventilation under circumstances that are often challenging, the distinction between the funnel or nonfunnel shape of the airway and whether the cricoid membrane serves as a “functional cuff” is ultimately irrelevant. The intubated pediatric patient in respiratory failure who requires emergency access to tertiary care via a pediatric critical care transport team will be among the most critical patients considered for transport. Multiple attempts at placing an optimal airway must be avoided and so must the need to replace a poorly performing uncuffed endotracheal tube with a cuffed endotracheal tube in the critically ill child. Ventilation is challenging during interfacility transport with such concerns as environmental extremes, flight physiology factors, space constraints, limited resources (such as finite amounts of compressed gasses and medications), and personnel constraints to consider. Replacing an endotracheal tube in the critically ill or injured child is extremely risky, even more so in the transport environment. In our experience, the ventilatory status of some patients was deemed too unstable for transport until a cuffed tube was placed. Some were transported by our team with acceptable but suboptimal ventilation to arrive at the pediatric intensive care unit where resources such as pediatric intensivists, trained respiratory therapists and registered nurses, anesthesia providers, and otorhinolaryngology providers were available to safely facilitate replacing the endotracheal tube.

Although our data indicated an approximately 2% difference in mortality rates, there was insufficient in-depth clinical information gathered to comment on the effect of using cuffed versus uncuffed endotracheal tubes. Further study on mortality rate with an increased population size is warranted.

Failure to Disinvest

Considering that Khine et al[16] released the legacy article on the use of cuffed tubes in children in 1997 and other authors have since followed, why are uncuffed endotracheal tubes still a “thing” after more than 21 years? The decision to retain old practices may be influenced by past experience and personal beliefs, peer pressure, and industry pressures such as marketing influences.[17] The relative infrequency with which the typical provider of adult medical care is called upon to place an endotracheal tube in a pediatric patient may be a contributing factor in a failure to disinvest. Simultaneous with an effort to disinvest in past practices must be an effort to implement a new standard.[17]

Outreach

Beginning with our awareness of a sentinel event in 2014, physician outreach efforts to targeted referring facilities were initiated. Additionally, video conferencing by a critical care intensivist physician with the transferring physician at the time of transfer request was begun in 2015. We found that with targeted physician outreach and physician involvement in the transport team intake process, the incidence of patients arriving with uncuffed endotracheal tubes decreased. An increase in arrivals with uncuffed endotracheal tubes in 2017 indicates a need to focus outreach on referral centers not previously targeted. We also began outreach to emergency medical services agencies who refer patients to our facility to encourage the prehospital use of cuffed endotracheal tubes. The first-pass relationship with cardiac arrest in the patient with acute respiratory distress, the mitigation of ventilation complications, and the avoidance of multiple invasive airway procedures are the basis for all of our outreach education.

Limitations

Our patients had a wide range of medical and traumatic conditions and were referred from outside facilities where initial treatment decisions were outside of our control. A variety of tube manufacturers were represented because there are dozens of facilities that refer patients. Our sample is indicative for only our hospital. Further study should be performed on a larger scale to determine general applicability.

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