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Changes in intracuff pressure of a cuffed endotracheal tube during prolonged surgical procedures

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ABSTRACT

Background: With the introduction of redesigned cuffed endotracheal tubes (ETTs), there has been an increasing trend toward their use in pediatric patients. Despite improvements in design, an unintended and prolonged hyperinflation of the cuff can compromise tracheal mucosal perfusion. The current study prospectively monitors changes in intracuff pressure continuously in pediatric patients undergoing prolonged surgical procedures.

Methods: The study was conducted on pediatric patients who were scheduled to undergo prolonged surgical procedures (more than 4 h) with a cuffed ETT. After placement of the cuffed ETT, the cuff was inflated using the air-leak test with a CPAP of 20 cmH_2O in the anesthesia circuit. After inflation, the inflating port of the pilot balloon was connected to the transducer of the invasive pressure monitoring device using our previously described technique to continuously measure the intracuff pressure. Measurements were recorded every 15 min for the first 1 h, and then every 30 min throughout the surgical procedure.

Results: The study cohort included 30 patients who ranged in age from 1.2 to 17.6 years and in weight from 9.4 to 113.4 kg. There were 16 boys and 14 girls. The size of the cuffed ETT ranged from 3.5 mm to 8.0 mm ID. The baseline intracuff pressure at the time of inflation was 17.6 ± 8.8 cmH_2O. The absolute change in the intraoperative intracuff pressure when compared to the baseline intracuff pressure ranged from −25.8 to +16.3 cmH_2O. In 9 patients (30%), the decrease of the intracuff pressure was $\geq$10 cmH_2O. In 6 patients (20%), the increase of the intracuff pressure was $\geq$10 cmH_2O. In 5 of 30 patients (17%), the absolute intracuff pressure was greater than 30 cmH_2O at least once intraoperatively. In no patient, did the intracuff pressure remain the same as the baseline throughout the procedure.

Conclusion: We noted significant variations in the intracuff pressure during prolonged surgical procedures. These unintended changes, both increases and decreases, may impact the perioperative course of patients. Our study suggests the need for continuously monitoring intracuff pressure if a cuffed ETT is used in children for prolonged surgical procedures.

1. Introduction

Although uncuffed endotracheal tubes (ETTs) had been used traditionally in pediatric anesthesia, there has been a recent change with a transition to the use of cuffed instead of uncuffed ETTs [1,2]. Reported advantages include a reduced incidence of the need to exchange the ETT; better airway seal resulting in more reliable ventilation and oxygenation; a more precise end-tidal carbon dioxide tracing; and decreased consumption of inhalational anesthetic agents [1,3–5]. However, even with the newer generation of ETTs, the risk of over-inflation of the cuff may still exist if the intracuff pressures are not maintained within the clinically recommended range [6,7]. Excessive intracuff pressure may result in decreased or compromised tracheal mucosal blood flow and the subsequent development of tracheal and subglottic complications. Although the intracuff pressure may be checked

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initially following the cuff inflation after endotracheal intubation, the intracuff pressure can be changed dynamically throughout the case because of the various clinical factors including variation in head and neck position, body temperature, and the composition of the inhaled gases including the use of nitrous oxide. There are currently no data in the pediatric population regarding changes in the intracuff pressure during prolonged surgical procedures in the operating room setting. The current study prospectively and continuously assesses changes in intracuff pressure during prolonged (more than 4 h) surgical procedures.

2. Methods

This study was a prospective observational study in a single institution (Nationwide Children's, Columbus, OH) to assess continuous intracuff pressure monitoring in pediatric patients undergoing prolonged surgical procedures. The study was approved by the Institutional Review Board of Nationwide Children's Hospital, Columbus, OH (IRB12-00715), which waived requirements for informed consent due to the observational nature of the study. The study was registered at ClinicalTrials.gov (NCT01738321). Inclusion criteria included patients less than 18 years of age who were scheduled for surgical procedures anticipated to last more than 4 h and requiring endotracheal intubation with a cuffed ETT.

There was no change in anesthetic care dictated by the study other than the continuous intracuff pressure monitoring. Anesthesia was induced with inhalational or intravenous agents based on the preference of the attending anesthesiologist. Endotracheal intubation was performed with some combination of an inhaled agent (sevoflurane), intravenous anesthetic agents (propofol and opioids), and as needed a neuromuscular blocking agent (NMBA). After endotracheal intubation with a cuffed ETT, the cuff was inflated by the anesthesia provider using our standard technique which involves placement of a stethoscope over the suprasternal notch with slow inflation of the cuff until there is no audible gas leak while holding continuous positive airway pressure of 20 cmH_2O with the head and neck in the neutral position. Given the standard practice in our operating rooms, after anesthetic induction, nitrous oxide is not used for maintenance anesthesia. Normothermia (36–37°) was maintained using forced air warming and alterations in the room temperature. After the cuff was inflated, the intracuff pressure was continuously monitored using our previously described and validated technique [8,9]. For this purpose, a transducer from a standard invasive pressure monitoring device that is routinely used to measure arterial or central venous pressure, is attached to the pilot balloon of the ETT. The pressure readings obtained in mmHg were converted to cmH_2O (1 mmHg = 1.36 cmH_2O). The intracuff pressure was recorded initially after endotracheal intubation, every 15 min for the first 1 h, and then every 30 min thereafter throughout the surgical procedure. When the intracuff pressure was greater than 30 cmH_2O, air was removed from the cuff until the intracuff pressure was within the desired range. Alternatively, air was added to the cuff, if there was an excessive loss of pressure with a gas leak leading to ventilation concerns (bellows not filling adequately).

3. Results

The cohort for the study included 30 patients who ranged in age from 1.2 to 17.6 years (9.9 ± 5.1 years) and in weight from 9.4 to 113.4 kg (40.7 ± 28.1 kg). There were 16 boys and 14 girls. The size of the cuffed ETT ranged from 3.5 mm to 8.0 mm ID. The procedures included 13 spinal surgeries, 4 intracranial surgeries, 4 laparotomies, and 9 other miscellaneous procedures. The patient positioning during the procedures was supine in 13 cases, prone in 14 cases, and lateral in 3 cases. The duration of intracuff pressure measurements ranged from 240 to 960 min.

The baseline intracuff pressure at the time of inflation immediately following endotracheal intubation was 17.6 ± 8.8 cmH_2O (median: 19.0 cmH_2O). In no patient, did the intracuff pressure remain at baseline throughout the surgical procedure. In 6 of the 30 patients (20%), the intracuff pressure increased from the baseline by more than 10 cmH_2O. In 2 cases (7%), air was removed from the cuff due to the sustained intracuff pressure above 30 cmH_2O. The intraoperative change in the intracuff pressure over the initial 6 h following endotracheal intubation is demonstrated in Fig. 1. The maximum increase in intracuff pressure from the baseline was 16.3 cmH_2O. In 5 of 30 patients (17%), the absolute intracuff pressure was greater than 30 cmH_2O at least once intraoperatively. Additionally, in 9 of the 30 patients (30%), the intracuff pressure decrease was more than 10 cmH_2O from baseline. In 7 of the 30 patients (23%), it was necessary to add air to the cuff due to intraoperative ventilation concerns including inadequate filling of the bellows with a low fresh gas flow (1–2 l/min^{-1}).

4. Discussion

In recent years, there has been a shift in the philosophy regarding the use of cuffed ETTs in pediatric population given the recognition of the reported advantages of using cuffed instead of uncuffed ETTs. However, care must be exercised with the intracuff pressure as the potential risk of over or under inflation of the still exists. Apart from the risk of over-inflation at the time of initial inflation, the pressure within the inflated cuff is a dynamic process and can be altered by various clinical factors [10,11].

An excessive intracuff pressure exerted on the tracheal wall may compromise perfusion of the mucosa and the underlying structures leading to perioperative complications. These may include sore throat, voice changes including hoarseness, subglottic injury, tracheal rupture, tracheal stenosis, and laryngeal nerve palsy. Although some variation can be found, it is generally accepted that the intracuff pressure should be limited to $\leq$20–30 cmH_2O in the majority of the pediatric population. The acceptable level for the intracuff pressure may be even lower in neonates and infants or those with co-morbid cardiovascular disease given the lower perfusion pressure to the tracheal mucosa [12]. On the other hand, under-inflation of the cuff may lead to a risk of aspiration or result in an excessive gas leak that interferes with effective ventilation and may impact operating room staff safety due to environmental pollution.

While a single measurement of the intracuff pressure following endotracheal intubation is suggested, the pressure within the inflated cuff is a dynamic process. It can be affected by changes in the size and shape of the trachea, changes in the level of anesthesia, the patient's body temperature, and the anesthetic gas mixture including the administration of nitrous oxide. There are limited data regarding the alterations of the intracuff pressure in adult patients in the intensive care setting and no previous data exploring the changes in the intracuff pressure which may occur during prolonged surgical procedures in pediatric population. In a pilot study, Sole et al. monitoring the intracuff pressure for an average of 9.3 h in 10 adult patients who were orally intubated and receiving mechanical ventilation. The initial cuff pressure was adjusted to a minimum of 20 cmH_2O. The pilot balloon of the endotracheal tube was connected to a transducer and the intracuff pressure was recorded every 0.008 s and then reduced to 1 min means. Only 54% of cuff pressure measurements were within the recommended range of 20–30 cmH_2O. The intracuff pressure was high in 16% of measurements and low in 30%. Although no statistically significant changes were noted over time, there were changes