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Changes in the cuff pressure in neonates in the absence of nitrous oxide

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Abstract

Background: Changes in the pressure of cuffed neonatal size tracheal tubes (TT) during anaesthesia without nitrous oxide are not well described. We determined whether the cuff pressure changes over time in neonates under general anaesthesia without nitrous oxide.

Methods: The airways of thirty neonates were secured with a high volume low pressure cuffed TT for meningocele surgery. The cuff was manually inflated until there was no audible leak and maintained at 10–15 cm H_2O throughout by monitoring the pressure continuously with both a manometer and a pressure transducer. At baseline, the cuff pressure was assessed in the supine and then prone positions. During surgery, if the pressure exceeded 15 cm H_2O, the cuff was deflated to < 15 cm H_2O and if it was < 10 cm H_2O, the cuff was inflated to 10–15 cm H_2O. The time interval between corrections and the number of corrections were recorded.

Results: The cuff pressures in 18 neonates (60%) required correction during surgery. The cuff pressure exceeded 15 cm H_2O in nine neonates (30%) and was corrected. The cuff pressures in 13 neonates were less than 10 cm H_2O and required correction. The gender, weight, height, and duration of anaesthesia did not differ significantly between neonates who required correction of the cuff pressure and those who did not. Mean cuff pressures were similar at 15, 45, and 75 minutes of anaesthesia.

Conclusions: In 60% of neonates undergoing surgery in the prone position under general anaesthesia without nitrous oxide, the cuff pressure exceeded 15 cm H_2O. In such cases, cuff pressure should be monitored continuously throughout the surgery.

Key words: neonate, cuff pressure, tracheal tube.

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The cuff pressure in tracheal tubes (TTs) should be as low as clinically acceptable to minimize the risk of TT-related airway complications. Several factors are known to affect the cuff pressure of TTs including the duration of anaesthesia, core temperature, neuromuscular blockade, sedation, altitude, the presence of nitrous oxide, tracheal muscle tone and respiratory system impedance, head and neck positions, mechanical ventilation and transoesophageal echocardiography probe insertion [1–10].

Some clinicians avoid the use of nitrous oxide (N_2O) during surgery because of the theoretical risk of deleterious effects on the neurologic, cardiovascular, hematologic and immune systems [11]. In addition, N_2O diffuses into air-filled cavities increasing the size of and pressure within the cavities including TT cuffs [12, 13].

However, changes in the cuff pressure of TTs in the absence of N_2O are poorly understood. Kako *et al.* [14] investigated the relationship between head and neck position and TT cuff pressure in 200 children in the absence of N_2O in the supine position. They reported that the cuff pressure increased in > 50% of the measurements (545 out of 1000 measurements) compared with the neutral position. Most frequently changes were noted with neck flexion with a mean increase in cuff pressure of 7.2 ± 8.3 cm H_2O ($P < 0.05$).

In the current study, we determined whether cuff pressure changes over time in neonates undergoing myelomeningocele repair in the prone position under general anaesthesia without N_2O.

METHODS

This prospective observational study was approved by the Institutional Review Board of our University (IRB# 44140529/2016-49). Written informed consent was obtained from the parents of 30 neonates who were scheduled for myelomeningocele repair. The trial was registered at https://www.anzctr.org.au (ACTRN12619000109101).

Anaesthesia was induced with a combination of oxygen, air, sevoflurane, intravenous remifentanil and rocuronium. After tracheal intubation with a high volume low pressure cuffed TT (Nextech, Istanbul, Turkey, internal diameter 2.5 mm/outer diameter 3.0 mm), the cuff was inflated until there was no audible gas leak. The observer checked the gas leak using a stethoscope guided inflation over the trachea while continuous positive airway pressure of 20–25 cm H_2O was maintained [15].

TABLE 1. Patient demographics, coexisting diseases, duration of anaesthesia, requirement for cuff pressure correction, and the time between corrections

Factor	Min-Max	Median	Mean ± SD/*n* (%)
Age (days)	1–14	3.0	4.3 ± 3.9
Gender			
Girl			18 (60.0)
Boy			12 (40.0)
Body mass (kg)	2260–3700	2845	2891 ± 281
Height (cm)	43.0–52.0	48.0	48.1 ± 2.3
Coexisting disease			
No			30 (100.0)
Yes			0 (0.0)
Duration of anaesthesia (min)	40–105	65.0	68.7 ± 18.8
Cuff pressure correction (decrease)			
No			21 (70.0)
Yes			9 (30.0)
Cuff pressure correction (increase)			
No			17 (56.7)
1 time			9 (30.0)
2 times			3 (10.0)
3 times			1 (3.3)
Time between two corrections			
No			22 (73.3)
10 min			2 (6.7)
15 min			1 (3.3)
20 min			2 (6.7)
25 min			1 (3.3)
40 min			2 (6.7)

A blind investigator monitored and recorded the cuff pressures. The baseline cuff pressure was assessed first in the supine position and then in the prone position. The head and neck were maintained in the neutral position in both the supine and prone positions for cuff pressure measurements and surgery. Thereafter, the TT cuff pressures were monitored manually, continuously and concurrently with both a cuff manometer and pressure transducer. The pressure transducer was monitored using a calibrated pressure transducer as described previously [16]. If the pressure was within 10–15 cm H_2O, no intervention was performed. If the pressure exceeded 15 cm H_2O, the cuff was deflated to less than 15 cm H_2O. The time when the cuff pressure correction occurred, the time interval between cuff pressure corrections and the number of corrections during surgery were recorded. The cuff pressures were compared over time within patients. In addition, heart rate, end-tidal CO_2, temperature and peak airway pressure were recorded every 15 min.

Statistical analysis

In previous clinical studies, investigators concluded that a 20% difference in cuff pressure achieved clinical significance [17]. We estimated that a sample size of 14 patients per group was required for a two-tailed α of 0.05, β of 0.1 and a standard effect size of 1.21 in order to achieve 90% power at a 5% significance level. To account for dropouts and incomplete data, 30 neonates were enrolled.

Data were evaluated for their distribution using the Shapiro-Wilk test. Data that were normally distributed are summarized as means ± standard deviation. Data that fit a skewed distribution are summarized as medians and 25–75th percentile. Cuff pressure and all other interval data that were measured over time were analysed using repeated-measures ANOVA with the Tukey (or Dunnett) post-hoc test. Cuff pressures in the supine and prone positions were analysed using ANOVA. Baseline demographic data were compared using the unpaired *t*-test for normally distributed data and the Mann-Whitney *U* test for skewed data. $P < 0.05$ was accepted as significant.

RESULTS

Thirty neonates completed the study. None of the neonates had coexisting disease. The demographic data of the neonates, the duration of anaesthesia and cuff pressure are presented in Table 1. The mean (± SD) age was 4.3 (± 3.9) days. The mean (± SD) duration of anaesthesia was 68.7 (± 18.8) min. The cuff pressures in 18 (60%) neonates were adjusted during surgery. The cuff pressures in 9 (30%) neonates exceeded 15 cm H_2O and were decreased during anaesthesia whereas the pressures in 9 (30%) other neonates were less than 10 cm H_2O. Of the latter 9, 4 required further increases in the cuff pressures (Table 1). The cuff pressure in 4 neonates (13%) required both an increase and a decrease during the surgery. Mean cuff pressures were similar at 15 min, 45 min and 75 min (Table 2). The cuff pressures were significantly greater at 15th min in neonates whose cuff pressures had been corrected already by reducing the pressure, 14.7 ± 1.4 mmHg vs. 12.3 ± 2.5 mmHg (Table 3). The cuff pressures at 45 min were significantly greater in neonates whose cuff pressures were corrected by increasing the cuff pressure, 16.5 ± 2.3 mmHg vs. 13.4 ± 2.3 mmHg (Table 4). The gender distribution, weight, height, temperature and duration of anaesthesia were similar among neonates who required correction of their cuff pressures and those who did not. No changes in ventilator settings were required during the study period.

TABLE 2. Cuff pressures at 15th, 45th and 75th min

Cuff pressure	Min–Max	Median	Mean ± SD	*P*-value
15th min	10–18	14.0	14.0 ± 2.1	0.359F
45th min	9–20	15.0	14.7 ± 2.8	
75th min	13–19	15.0	15.1 ± 1.7	

FFriedman test

DISCUSSION

In this prospective observational study, significant changes in cuff pressure were identified in 60% of neonates who required adjustment in the prone position under general anaesthesia without N_2O. The frequency of decreasing and increasing the cuff pressures were similar.

Cuffed TTs are widely recommended for use in paediatric patients, since they offer a number of advantages over the uncuffed TT [18]. A number of pa-

TABLE 3. Comparison of neonates with decreased cuff pressure and no intervention

Factor	No intervention		Decreased cuff pressure		*P*-value
	Mean ± SD/*n* (%)	Median	Mean ± SD/*n* (%)	Median	
Age (days)	4.8 ± 4.4	3.0	3.1 ± 2.0	3.0	0.220m
Gender					
Girl	13 (61.9)		5 (55.6)		0.745χ^2
Boy	8 (38.1)		4 (44.4)		
Weight (kg)	2900 ± 254	2850	2872 ± 352	2840	0.659m
Height (cm)	48.0 ± 2.3	48.0	48.3 ± 2.4	49.0	0.892m
Duration of anaesthesia	71.4 ± 20.5	70.0	62.2 ± 13.0	60.0	0.680m
Cuff pressure					
15th min	14.7 ± 1.4	15.0	12.3 ± 2.5	13.0	0.003m
45th min	15.3 ± 1.8	15.0	13.3 ± 4.0	12.0	0.201m
75th min	15.4 ± 1.8	15.0	14.0 ± 1.0	14.0	0.171m

mMann-Whitney *U* test/χ^2 test

TABLE 4. Neonates with increased cuff pressure and no intervention

Factor	No intervention		Increased cuff pressure		*P*-value
	Mean ± SD/*n* (%)	Median	Mean ± SD/*n* (%)	Median	
Age (days)	4.6 ± 4.5	3.0	3.8 ± 3.1	3.0	0.025m
Gender					
Girl	10 (4.6)		8 (61.5)		0.880χ^2
Boy	7 (3.2)		5 (38.5)		
Weight (kg)	2809 ± 230	2800	2999 ± 313	2920	0.897m
Height (cm)	48.1 ± 2.2	48.0	48.0 ± 2.6	48.0	0.194m
Duration of anaesthesia	62.1 ± 17.5	60.0	77.3 ± 17.5	75.0	0.949m
Cuff pressure					
15th min	13.6 ± 1.4	13.0	14.5 ± 2.7	15.0	0.100m
45th min	13.4 ± 2.3	15.0	16.5 ± 2.3	16.0	0.001m
75th min	14.5 ± 0.6	14.5	15.4 ± 2.1	15.0	0.590m

mMann-Whitney *U* test/χ^2 test

tient safety-enhancing features support this choice including increasingly accurate physiological measurements (such as peak inspiratory and end-tidal carbon dioxide pressure), and a reduction in TT gas leakage. American Heart Association and European Resuscitation Council guidelines for paediatric advanced life support recommend cuffed TTs as a safe alternative to uncuffed TTs [19, 20]. Moreover, thin polyurethane Microcuff TTs are used increasingly in place of uncuffed TTs in infants and neonates [21, 22]. However it is obvious that more evidence is needed for their use in newborns [20].

Previous studies have evaluated cuff pressure changes due to positional changes in paediatric patients [14, 23]. The average age range in the present study was 1 to 14 days. Neonates whose lungs are mechanically ventilated while in the prone position are particularly susceptible to sudden accidents such as accidental extubation, bleeding or loss of the airway [24]. In our study, neck flexion, head extension and left or right rotations during positioning were possible causes of changes in cuff pressure. We found a similar number of neonates with cuff pressures that exceeded 15 cm H_2O necessitating a decrease in pressure as those with cuff pressures that required inflation. Additionally, 4 patients required both increases and decreases in cuff pressure during anaesthesia.

Overall, the cuff pressure decreased below our acceptable threshold of 15 cm H_2O in more neonates. Several possible reasons for this finding include intraoperative hypotension, hypothermia and prolonged surgery [25, 26]. Changes in the position of the head and neck can affect the TT cuff pressure; in 68% of the children, the cuff pressure increased [14]. The most dramatic increase was noted with neck flexion in children less than 8 years of age. In 19% of patients, intracuff pressure decreased, especially due to neck extension. In the current study, neonates had a low risk of neck flexion in the prone position. Studies have also concluded that the use of intraoperative muscle relaxants reduces cuff pressure [27]. With the loss of muscle tone, the laryngeal dimensions may increase while the oropharyngeal dimension decreases [28]. Moreover, neonates are more sensitive to muscle relaxant agents than are older children [29]. They display proportionately longer action times. The decrease in cuff pressure in this study is most likely attributed to the use of non-depolarizing muscle relaxant agents.

Based on the changes observed in the cuff pressures in this study, we recommend that cuff pressures in neonates in the prone position should be measured continuously after positioning. This practice will reduce the risk of accidental extubation or pulmonary microaspiration due to inappropriate cuff pressure. In addition, monitoring cuff pressure will prevent excessive tracheal mucosal pressure from the cuff even in the absence of nitrous oxide.

LIMITATIONS

An important limitation of our study was the small sample size. The sample size was based on a set of reasonable assumptions; thus it was unethical to enrol more neonates. The downside of the small sample size is the limited ability to identify infrequent complications. In this study, we measured intracuff pressure continuously. Electronic or pneumatic intracuff pressure controllers are available to maintain a constant cuff pressure within a prescribed range. Their cost and complexity restrict the use of these devices in everyday anaesthesia. Transducer-based measurement systems can alarm if the pressures are outside a prescribed range, but the correction cannot be performed automatically.

CONCLUSIONS

Among neonates undergoing surgery in the prone position without the use of nitrous oxide, cuff pressure changed in 60%, necessitating an adjustment in the pressure. Thus, cuff pressure should be measured continuously either before or after positioning because the pressure may increase or decrease during the procedure.

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