Original Article

Endotracheal tube cuff pressure monitoring during neurosurgery - Manual vs. automatic method

Mukul Kumar Jain, Chander Bhushan Tripathi[1]

Department of Neuroanesthesiology and [1]Biostatistics, Institute of Human Behavior and Allied Sciences, Dilshad Garden, Delhi, India

Abstract

Background: Inflation and assessment of the endotracheal tube cuff pressure is often not appreciated as a critical aspect of endotracheal intubation. Appropriate endotracheal tube cuff pressure, endotracheal intubation seals the airway to prevent aspiration and provides for positive-pressure ventilation without air leak.

Materials and Methods: Correlations between manual methods of assessing the pressure by an experienced anesthesiologists and assessment with maintenance of the pressure within the normal range by the automated pressure controller device were studied in 100 patients divided into two groups. In Group M, endotracheal tube cuff was inflated manually by a trained anesthesiologist and checked for its pressure hourly by cuff pressure monitor till the end of surgery. In Group C, endotracheal tube cuff was inflated by automated cuff pressure controller and pressure was maintained at 25-cm H_2O throughout the surgeries. Repeated measure ANOVA was applied.

Results: Repeated measure ANOVA results showed that average of endotracheal tube cuff pressure of 50 patients taken at seven different points is significantly different (F-value: 171.102, *P*-value: 0.000). Bonferroni correction test shows that average of endotracheal tube cuff pressure in all six groups are significantly different from constant group ($P = 0.000$). No case of laryngomalacia, tracheomalacia, tracheal stenosis, tracheoesophageal fistula or aspiration pneumonitis was observed.

Conclusions: Endotracheal tube cuff pressure was significantly high when endotracheal tube cuff was inflated manually. The known complications of high endotracheal tube cuff pressure can be avoided if the cuff pressure controller device is used and manual methods cannot be relied upon for keeping the pressure within the recommended levels.

Key words: Automatic cuff pressure controller, endotracheal tube cuff pressure, manual method, neurosurgery

Introduction

Securing and maintaining airway and ventilating the patients by placement of endotracheal tube (ETT) is common practice in the operation theater for delivery of general anesthesia and in the critical care settings. Use of cuffed tube for safer anesthetic practice[1,2] and checking the ETT cuff (ETTc) pressure by traditional methods as palpating the pilot balloon and hearing the disappearance of the audible air leak was considered adequate for assessment of ETTc pressure. ETTc pressure should be not more than 25 cm of H_2O (20-30 cm of H_2O) to maintain tracheal mucosa perfusion and thereby prevent mucosal ischemia, tracheal necrosis, rupture, stenosis, laryngeal nerve palsy and tracheoesophageal fistula. Nitrous oxide use may increase ETTc pressure perioperatively. It has long been believed, without any evidence-based data, that trained clinicians are capable of determining proper ETTc pressures. It is presumed that clinicians can detect appropriate inflation pressure and overinflated ETTc by palpating the ETT pilot balloon.

We evaluated whether trained anesthesiologists inflated ETTc appropriately and could keep the pressure within the permissible limit of 20-30 cm of H_2O using manual methods. We then checked the ETTc pressure by a cuff pressure monitor connected to the lock of ETT pilot balloon. This pressure was set at 25 cm of H_2O and then monitored hourly. We also compared this group of patients with another group whose cuff was inflated by an automatic cuff pressure controller and the cuff pressure was set at 25 cm H_2O throughout the surgery.

Address for correspondence: Dr. Mukul Kumar Jain,
Department of Neuroanaesthesiology, Room No. 118,
Academic Block, Institute of Human Behavior and Allied Sciences,
Dilshad Garden, Delhi, India.
E-mail: jainmukul2004@yahoo.com

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Materials and Methods

After obtaining the institutional ethical committee clearance and written consent of patients, 100 patients were randomly selected of either sex and age between 20 and 50 yrs of ASA grade I/II and MPG I/II. All the patients were posted for either craniotomy or spine surgery under general anesthesia. All emergency intubations, pregnant patients, full stomach, trauma cases, anterior cervical spine surgeries and patients with predicted difficult intubation were excluded from the study. The study was a prospective observational study by trained anesthesiologists. The anesthesiologists who were responsible for the inflation of the cuff were blinded, as they were unaware of the study.

These patients were divided into two groups: In group M, of 50 patients, ETTc was inflated manually by a trained anesthesiologist and checked for its pressure hourly by cuff pressure monitor; and in group C, of 50 patients, ETTc was inflated by automatic cuff pressure controller and pressure was maintained at 25 cm H_2O throughout the surgeries. High volume, low pressure cuff, single use, oral flexometallic ETT (Portex Reinforced Tracheal Tube, Smiths Medical International Ltd, UK) with internal diameter 7.0-8.5 mm were used in all patients. The safe cuff pressure in our study protocol was taken as any pressure less than 25 cm of H_2O. This ETTc pressure was measured by highly sensitive and accurate VMB cuff controller (Cuff controller digital 0-99 cm H_2O, VMB Medizintechnik GMBH, Germany).

After induction of anesthesia with propofol and administration of vecuronium, oral endotracheal intubation was done with appropriate size ETT. In group M, for cuff inflation standard technique consisted of ETTc inflation using a syringe to inject air into the cuff and assessment of cuff pressure by palpation of the external pilot balloon and by listening for disappearance of the audible air leak by an anesthesiologist with at least 5-year experience. After this ETTc pressure was recorded and monitored hourly. In group C, ETTc was inflated by attaching with automatic cuff pressure controller and pressure was maintained at 25 cm H_2O throughout the surgeries. Patients were maintained on oxygen + nitrous oxide (1:2), isoflurane, fentanyl and vecuronium.

ETTc pressure after manual inflation, any effect of body mass index (BMI) on ETTc, any effect of ETTc on delivered tidal volume/end-tidal carbon dioxide ($EtCO_2$)/airway pressure, any change in the ETTc during surgery, and complications (if any) were observed. All the statistics was done with the help of latest PASW 18. Descriptive statistics were calculated for all the variables and repeated measure ANOVA was applied to verify that whether the ETT pressure is significantly different in all the groups or not. Before applying repeated measure ANOVA, the assumption of sphericity was also verified. All the statistical analysis was carried out on PASW 18 software.

Results

Table 1 shows the demographic data of the two groups. The groups were comparable demographically in respect of age, sex, weight, height and BMI. The $EtCO_2$ level, tidal volume and airway pressure were also comparable. There was no case of air leak from side of ETTc in the two groups. Mean duration of surgery was 5.2 hrs.

Table 2 shows the average ETTc pressure in both groups along with their standard deviation (SD). In group M, average manual pressure at baseline was much higher than that measured at later points of time. Mean ETTc pressure increased with passage of time. Figure 1 graphically displays ETTc pressure levels in relation to time during the surgery in the two groups. ETTc pressure was higher all time in group M in comparison to Group C.

In group C, as there was constant ETTc pressure of 25 cm H_2O, there was no need of statistical calculations. Group M and group C could not be compared as one group was

Table 1: Demographics profile

Variables	Group M Mean ± SD (N = 50)	Group C Mean ± SD (N = 50)
Age	45.560 ± 10.940	46.820 ± 10.440
Sex (M:F)	24:26	27:23
Weight	55.812 ± 9.270	57.698 ± 9.518
Height	161.076 ± 6.040	161.145 ± 7.034
BMI	21.479 ± 3.166	22.132 ± 2.775
$EtCO_2$	33.110 ± 1.792	33.432 ± 1.765
Tidal volume	448.600 ± 71.771	465.600 ± 72.847
Airway pressure	18.866 ± 0.579	18.696 ± 0.432
Air leak from side of ETTc	Nil	Nil

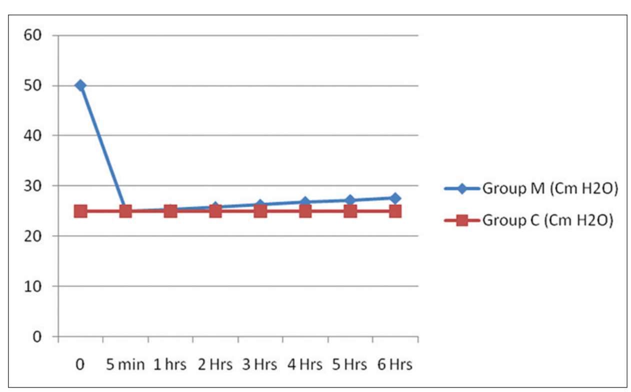

Figure 1: Comparison of ETTc pressure at different time in different groups

Table 2: ETTc pressure at different time interval in both groups

ETTc pressure	N	Group M (Mean ± SD)
Manual pressure (cm of H_2O), Baseline	50	50.100 ± 11.671
Pressure set after measuring by cuff pressure monitor (cm of H_2O)	50	25.000 ± 00
ETTc pressure after 1 hrs (cm of H_2O)	50	25.240 ± 0.517
ETTc pressure after 2 hrs (cm of H_2O)	50	25.780 ± 0.790
ETTc pressure after 3 hrs (cm of H_2O)	50	26.260 ± 0.723
ETTc pressure after 4 hrs (cm of H_2O)	50	26.820 ± 0.850
ETTc pressure after 5 hrs (cm of H_2O)	50	27.240 ± 0.916

ETTC:

Table 3: Repeated measure ANOVA result of ETTc pressure in group M

Source	F-value	*P*-value
ETTc pressure (main effect) Greenhouse-Geisser	165.998	0.000*
ETTc pressure*EtCO$_2$ (interaction effect) Greenhouse-Geisser	1.410	0.242
ETTc pressure*tidal volume (interaction effect) Greenhouse-Geisser	0.028	0.873
ETTc pressure*airways pressure (interaction effect) Greenhouse-Geisser	0.165	0.693
ETTc pressure*EtCO$_2$*tidal volume (interaction effect) Greenhouse-Geisser	0.064	0.808
ETTc pressure*EtCO$_2$*airways pressure (interaction effect) Greenhouse-Geisser	2.258	0.140
ETTc pressure*tidal volume*airways pressure (interaction effect) Greenhouse-Geisser	0.230	640
ETTc pressure*EtCO$_2$*tidal volume*airways pressure (interaction effect) Greenhouse-Geisser	1.064	0.310
Error (ETTc pressure) Greenhouse-Geisser	-	-

ETTC:

constant. As ETTc pressure on the same subjects was measured repeatedly at different point of time, the repeated measure analysis of variance technique was applied to find out the overall difference in ETTc pressure level measured at different point of time. After having significant different result from repeated measure ANOVA, the multiple comparisons analysis with Bonferroni correction test was applied to compare each time measured pressure with constant pressure. ETTc pressure were categorized into two groups on the basis of mean value of $EtCO_2$ (<33 and ≥ 33), tidal volume (<448 and ≥ 448) and airway pressure(<19 and ≥ 19) each and taken into consideration as factors at time of conducting repeated measure ANOVA to measure the interaction effect. Before interpreting the repeated measure ANOVA result, the assumption of sphericity (the level of dependence between pairs of groups is roughly equal or not) may be verified with Mauchly's test statistics. In our present study, the assumption of sphericity has been violated ($P = 0.000$) and estimate of sphericity (ε-value) is less than 0.75, so Greenhouse-Geisser correction has been taken into consideration for repeated measure ANOVA result.

Repeated measure ANOVA results [Table 3] showed that average of ETTc pressure of 50 patients taken at seven different point was significantly different (F-value: 171.102, *P*-value: 0.000) meaning that at least one average of ETTc pressure was statistically different from rest six point groups. Interaction effect between ETTc pressure and $EtCO_2$, ETTc pressure and tidal volume, ETTc pressure and airway pressure, ETTc pressure and $EtCO_2$ and tidal volume, ETTc pressure and $EtCO_2$ and airway pressure, ETTc pressure and tidal volume and airway pressure and ETTc pressure and $EtCO_2$ and tidal volume and airway pressure were not significantly different. To explore which group was significantly different from first (constant group) group, multiple comparison analysis (Bonferroni correction test) was applied. Bonferroni correction test showed that average ETTc pressure at all six points were significantly different from that of the constant group ($P = 0.000$).

Table 4: Postoperative complications

Complication	Group M (n–50)	Group C (n–50)
Sore throat	10	4
Cough	6	4
Hoarseness of voice/laryngeal nerve palsy	1	0

Table 4 shows the incidence of postoperative complications. The main complications seen were sore throat, cough and hoarseness of voice. The rate of incidence of complications was higher in group M. No case of laryngomalacia, tracheomalacia, tracheal stenosis, tracheoesophageal fistula or aspiration pneumonitis was observed.

Discussion

Cuff pressure should be maintained around 25 cm H_2O in critically ill intubated and mechanically ventilated patients.[3,4] When ETTc pressure exceeds the capillary perfusion pressure of the tracheal mucosa, mucosal blood flow is obstructed lead to severe, even fatal injury[5,6] including tracheal pain or stridor.[5,7] Other complications of overinflation of the cuff include nerve palsy,[3] tracheoesophageal fistula,[8] tracheal wall damage,[9] subglottic scarring or stenosis and hoarseness. Under-inflation of ETTc is associated with inadequate delivery of prescribed tidal volume and aspiration of secretions.[10,11] Pressures greater than 40 cm H_2O have been reported in 91% of postoperative patients after nitrous oxide anesthesia and in 45% of patients receiving other anesthetics.[11]

The suggested "safe" pressure to prevent aspiration and leaks past the cuff is 25 cm H_2O as capillary perfusion is not impaired.[3,6] However, after an *in vitro* study, Seegobin and Hasselt recommended that cuff inflation pressure not exceed 30 cm H_2O.[9] It is essential to maintain cuff pressures in the range of 20-30 cm of H_2O.[12] The precise pressure at which an individual may experience impaired or obstructed tracheal mucosal blood flow will depend upon numerous factors, most importantly the blood pressure.[13] Other important factors to avoid damage include adjusting cuff inflation for altitude, correct positioning of the patient's head and neck during intubation, avoiding infection involving the patient's secretions, preventing severe respiratory failure, and avoiding prolonged intubation.[3,12,13] Endotracheal suctioning, coughing and positioning affect ETTc pressure. In neurosurgery, as awkward positioning of head and neck after intubation is a common the risk of tracheal mucosal damage is more. This when coupled with overinflation of ETTc during prolonged surgeries it may lead to severe postoperative complications.

In patients undergoing for GA using high-volume, low-pressure ETT, use of automated cuff pressure monitor enables effective continuous control of the ETTc pressure. This effective control of cuff pressure, however, did not result in any difference with regard to tracheal mucosal damage. The severity of tracheal damage is related to the duration of intubation.[12] In a study of 93 patients, Sengupta *et al*.[14] observed that in 27% cases, ETTc pressure exceeds 40 cm H_2O irrespective of experience of anesthesia providers. We have demonstrated a higher incidence of ETTc pressure exceeding the safe limit as our safe limit was more conservative (25 cm H_2O).

This study demonstrates that even experienced anesthesiologists were unable to inflate an ETTc to a safe pressure limit. The manual methods as palpation of pilot balloon and disappearance of audible air leak are inaccurate methods to assess adequate ETTc pressure and most of the time it resulted in ETTc pressure more than the safe limit. The inability of clinicians to determine ETTc pressure by the traditional standard method of palpation of the pilot balloon has been addressed by other investigators.[1,11,13] Using standardized instruments to measure cuff pressures might help increase safety by decreasing the possibility of injury resulting from endotracheal intubation.[1,15,16]

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