

# Estimation of Endotracheal Tube Cuff Pressure in a Large Teaching Hospital in Ghana

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## Abstract

**Background:** Maintenance of optimal Endotracheal Tube cuff Pressure (ETTcP) in anaesthetic practice reduces cuff pressure complications. Aneroid manometers for measurement of ETTcP are not widely available in Ghana, hence anaesthesia providers estimate ETTcP according to their experience. The study assessed ETTcP obtained from estimation techniques between anaesthesia providers at Korle-Bu Teaching Hospital (KBTH). It also evaluated the Volume of Air Required (VAR) to obtain an acceptable cuff inflation pressure for sizes 7.0 and 8.0 mm adult endotracheal tubes used at the hospital, and the effect of patient's age, weight and height on this volume. **Methods:** Eighty-one patients who underwent general anaesthesia were recruited. ETTcP was measured using an aneroid manometer via a three-way tap. After full cuff deflation, the cuff was refilled with air until an ETTcP of 20 cm H<sub>2</sub>O was obtained. Independent t-test was used to measure the statistical variations in the ETTcP using estimation techniques in relation to recommended levels as well as the significant difference of mean VAR to obtain a cuff pressure of 20 cm H<sub>2</sub>O. Grouped t-test was used to determine significant differences in ETTcP between anaesthesia providers using estimation techniques. **Results:** Mean ETTcP obtained from estimation techniques was (61.87, 73.79) cm H<sub>2</sub>O. The mean ETTcP measured for Physician and Nurse Anaesthetists were 65.36 cm H<sub>2</sub>O and 69.52 cm H<sub>2</sub>O respectively. The mean VAR to achieve an ETTcP of 20 cm H<sub>2</sub>O for endotracheal tube sizes 7.0 mm and 8.0 mm were 3.90 ± 1.13 mls and 4.55 ± 0.95 mls respectively. Age and

weight significantly influenced the VAR to achieve a cuff pressure of 20 cm H<sub>2</sub>O, however, height did not. **Conclusions:** This study demonstrated that cuff pressures obtained by estimation techniques were generally higher than the recommended average with no significant difference between anaesthesia providers. However, in the absence of an aneroid manometer, ETTcP of tube sizes 7.0 mm and 8.0 mm can be safely approximated to the recommended levels with predetermined inflation volumes.

## Keywords

**Endotracheal Tube Cuff Pressure, Physician Anaesthetist, Nurse Anaesthetist, Korle-Bu Teaching Hospital**

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## 1. Introduction

General anaesthesia with endotracheal intubation and mechanical ventilation is utilized in many surgical procedures to maintain adequate ventilation for the patient. Large volume cuffs are ideal for generating low seal pressures [1]. High volume low pressure endotracheal tube cuffs are able to achieve minimal lateral tracheal wall pressure by affecting a clinical airtight seal at low intracuff pressures allowing delivery of predetermined tidal volumes into the lungs [2].

However, these cuffs can also generate high intracuff and lateral tracheal wall pressures when inflated beyond the seal pressure. Cuff pressures greater than 30 cm H<sub>2</sub>O are known to obstruct tracheal capillary blood flow with total occlusion of flow occurring at pressures above 50 cm H<sub>2</sub>O [3].

Both excessive and under inflation of endotracheal tube cuffs have adverse complications [4]-[8]. This, notwithstanding, is notable that most clinicians give little attention to inflation pressure of the endotracheal tube cuff, and simply determine the cuff pressure by estimation techniques according to their experience. These estimation techniques of endotracheal tube cuff pressure have nonetheless been found to be unreliable [9]-[11].

Aneroid manometers for accurate measurement of endotracheal tube cuff pressure are not widely available in Ghana and most Ghanaian anaesthesia providers are inexperienced in its use.

Various studies have been conducted with mixed results on experience-based estimation techniques with few of such studies conducted in Ghana. This study therefore seeks to measure the variations of endotracheal tube cuff pressure obtained by estimation techniques and determine its significance in respect to anaesthesia provider groups at Korle-Bu Teaching Hospital.

Endotracheal tube cuff pressures have been recommended to be between 20 - 30 cm H<sub>2</sub>O [3] [12] [13]. Various studies on determination of endotracheal tube cuff pressure by estimation techniques have shown that these techniques are not accurate in maintaining the cuff pressure within the recommended levels. Most of the cuff pressures obtained from these studies were above 30 cm H<sub>2</sub>O with few below 20 cm H<sub>2</sub>O [14]-[22].

A lot of studies have been done concerning user experience and the method of inflation of endotracheal tube cuff in relation to the pressure obtained. There are conflicting results concerning the relation between user experience and the cuff pressure obtained in relation to the use of estimation techniques in cuff pressure measurement. Whilst some studies noted that the experience of a user had a significant effect on the endotracheal tube cuff pressure measured by estimation techniques, [23] other studies found no significant difference between the cuff pressure and the experience of anaesthesia provider [22] [24]-[26].

Wujtewicz *et al.* in 2002 and 2009 noted that errors in estimating endotracheal tube cuff pressure do not improve with experience and in fact tendency to over inflate endotracheal tube cuff is even more among highly experienced users [27].

Most of the studies on endotracheal tube cuff pressure estimations were situated within the health systems of the developed world, whilst Africa and Ghana in particular have little coverage in the experience of endotracheal tube cuff pressure practices and measurement.

The aim of the study was to assess whether cuff pressures obtained from estimation techniques at Korle-Bu Teaching Hospital differed significantly from the recommended levels of 20 - 30 cm H<sub>2</sub>O and whether it differed significantly between Physician and Nurse Anaesthetists at the Hospital. In addition, the study also sought

to determine an estimated Volume of Air Required (VAR) for cuff inflation to obtain an acceptable cuff pressure for the commonest adult endotracheal tubes used at the hospital in the absence of an aneroid manometer. The study further sought to determine the influence of patients' demographic characteristics on this VAR. Not only would this contribute to filling the gap in literature on endotracheal tube cuff pressure procedures in Ghana but also influence clinical policy to adopt mandatory monitoring of cuff pressures or its safe estimation in the absence of aneroid manometers.

## 2. Materials and Methods

### 2.1. Study Design

A cross sectional study was conducted at the surgical theatre suite of the Korle-Bu Teaching Hospital (KBTH) between October 2012 and January 2013.

### 2.2. Study Site

The survey site was the Korle-Bu Teaching Hospital, a tertiary health care facility in Ghana. It has a bed capacity of 2000 and over 3000 staff according to the annual report of the Korle-Bu Teaching Hospital, 2013. An average of 29, 757 clients are seen per month, average daily outpatient attendance is 1500 and average daily admission is 150.

### 2.3. Subjects/Target Population

The study population was elective surgical patients presenting for general surgical procedures (such as mastectomy, cholecystectomy, hernia repairs, excision of intra-abdominal tumours etc.) at the hospital and who gave their informed consent except:

- 1) Patients who had cough and sore throat before operation;
- 2) Patients with difficult endotracheal intubation and repeated endotracheal intubations;
- 3) Pregnant women;
- 4) Patients with known anatomical abnormalities of larynx and trachea;
- 5) Patients whose surgical procedures were done in the prone position;
- 6) Patients below the age of twelve years;
- 7) Emergency patients with full stomach;
- 8) Patients who were intubated with endotracheal tube sizes other than 7.0 mm and 8.0 mm RÜSCH Polyvinylchloride tube.

### 2.4. Sampling and Sample Size Determination

Using Open Epi 2010 and considering a standard deviation value of 21.6 [22] to detect a mean pressure of 10 cm H<sub>2</sub>O over and above the recommended value of 20 - 30 cm H<sub>2</sub>O at a 95% confidence level and 80% statistical power, 63 sample units was required. Accounting for 10% non-response gave us 73 sample units. However, the study involved eighty-one (81) patients made up of 49.4% males and 50.6% females. The study involved 33 (40.7%) Physician Anaesthetists and 48 (59.3%) Nurse Anaesthetists who anaesthetised the patients randomly. Patients who met the inclusion criteria and gave their informed consent were recruited consecutively until the required sample size was obtained.

### 2.5. Procedure Used

After obtaining an ethical and protocol review approval, anaesthesia providers were not informed of the intention of determination of endotracheal tube cuff pressure measurement practices. This was done in order to protect possible manipulation of the results. To further avoid bias each anaesthesia provider anaesthetised only one of the sampled cases. General anaesthesia was induced by intravenous bolus of induction agent (thiopentone or propofol) and intubation and subsequent paralysis was achieved solely with vecuronium. Patients were intubated with RÜSCH high volume low pressure cuff endotracheal tube (7.0 mm for females and 8.0 mm for males). Anaesthesia providers insert the endotracheal tube and the cuff is either inflated by the provider himself or by the assistant. The anaesthesia provider always checks that the cuff is properly inflated using an estimation tech-

nique based on their experience. Cuff pressures obtained by estimation techniques were measured by the investigator directly using aneroid manometer (RÜSCH Endotest for low pressure cuffs, CE 0124, made in Germany) via a three way tap after 5 minutes of intubation (after securing the endotracheal tube). The estimation techniques used by the anaesthesia providers were also noted. The aneroid manometer measures pressures from 0 - 120 cm H<sub>2</sub>O. A syringe was then used to fully empty the cuff via the 3<sup>rd</sup> port of the three way tap. The cuff was then refilled with air in increments of 1.0 ml until a cuff pressure of 20.0 cm H<sub>2</sub>O was obtained. The Volume of Air Required to obtain a cuff pressure of 20 cm H<sub>2</sub>O was noted. The cuff pressure was maintained at 20 cm H<sub>2</sub>O thereafter. Anaesthesia was maintained with an inhalational agent (halothane or isoflurane) in an oxygen-air mixture. Nitrous oxide was not used in this study. The demographic characteristics of the patients (age, weight and height) were also documented.

## 2.6. Data Analysis

Data was captured using Microsoft Excel 2007 Database. Analysis was done with Statistical Package for the Social Sciences (SPSS) software version 18.0. Survey data were analyzed by simple descriptive statistics (*i.e.* mean, proportions, ratios and percentages) and summarized in tables. An independent t-test was used to measure the statistical variations in the cuff pressures using estimation techniques in relation to recommended levels as well as the significant difference of mean volume of air required to achieve a cuff pressure of 20 cm H<sub>2</sub>O. Grouped t-test was used to determine the significant differences in cuff pressure among doctors and nurses using estimation techniques at the 95% confidence interval. A p-value of < 0.05 was judged as significant.

## 2.7. Ethical Issues

Ethical Approval for the survey was obtained from the Ethical and Protocol Review Committee of University of Ghana Medical School (Protocol Identification Number: MS-Et/M.3-P4.4/2012-2013). Clearance was also received from the Management of the Korle-Bu Teaching Hospital and Heads of Clinical units where survey was conducted.

## 3. Results

### *Demographic Characteristics*

The study involved eighty-one (81) patients made up of 49.4% males and 50.6% females. The mean age (years), weight (kg) and height (cm) of the patients was 45.4 years, 77.0 kg and 164.2 cm respectively (**Table 1**).

### *Type of Anaesthetic Provider*

The study involved 33 (40.7%) Physician Anaesthetists (PA) and 48 (59.3%) Nurse Anaesthetists (NA) who anaesthetised the patients.

### *Technique of cuff pressure measurement by anaesthesia providers*

Out of the 33 physician anaesthetists, 32 used an estimation technique to measure the cuff pressure whilst one did not measure nor estimate the cuff pressure at all during general anaesthetic procedures.

All the 48 nurse anaesthetists measured the cuff pressure using an estimation technique (**Table 2**).

### *Endotracheal Tube Logistics*

The endotracheal tube sizes used for the study were 7.0 mm, 40 (49.4%) and 8.0 mm, 41 (50.6%).

*Percentages of endotracheal tube cuff pressure measured after intubation by anaesthesia providers for various ranges.*

Of the eighty-one (81) cases, 6.25% of the cuff pressures measured were within the recommended range of 20 - 30 cm H<sub>2</sub>O, 15% of cuff pressures measured were between 30 - 40 cm H<sub>2</sub>O and 78.75% of measured cuff

**Table 1.** Descriptive summary of age, weight and height of patients.

Factor	N	Minimum	Maximum	Mean	Std. Deviation
Age of patients	81	15	78	45.4	14.7
Height of patients	81	148	187	164.2	8.5
Weight of patients	81	42	126	77.0	18.1

Source: research survey.

pressures were above 40 cm H<sub>2</sub>O. None of the measured cuff pressure were below 20 cm H<sub>2</sub>O (Figure 1).

#### Assessment of Recommended Mean Interval

The study sought to assess whether endotracheal tube cuff pressures obtained after intubation by anaesthesia providers differed significantly from the recommended range of 20 - 30 cm H<sub>2</sub>O. A confidence interval measure was used to determine the mean interval of the sampled observations within a 95% confidence. The results indicated a mean endotracheal tube cuff pressure of 67.83 cm H<sub>2</sub>O with a 95% Confidence Interval of (61.87, 73.79; Table 3).

#### Endotracheal Tube Cuff Pressure per Anaesthetic Provider Group

An independent t-test was used to measure the mean differences in endotracheal tube cuff pressure per anaesthesia provider group at a significance level of 5%. The results indicated that the mean endotracheal tube cuff pressure obtained after intubation by Physician Anaesthetists and Nurse Anaesthetists were 65.36 cm H<sub>2</sub>O and 69.52 cm H<sub>2</sub>O respectively (Table 4) and that there was no statistically significant difference between the mean cuff pressure of the various anaesthesia provider groups ( $p < 0.499$ ; Table 4). The endotracheal tube cuff

**Table 2.** Method of measuring endotracheal tube cuff pressure by anaesthesia providers.

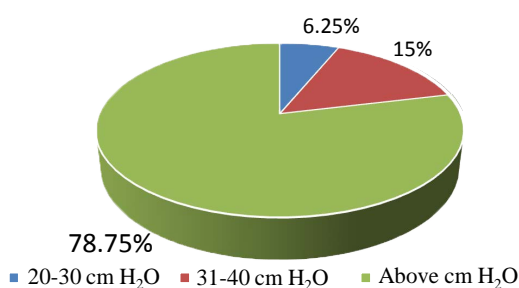
Method of measuring endotracheal tube cuff pressure	Physician Anaesthetist	Nurse Anaesthetist
Use of Aneroid Manometer	0	0
Estimation Methods		
Minimal Leak Technique	7	8
Palpation of pilot balloon cuff	20	28
Minimal Occlusive Technique	2	3
Use of Predetermined Volume Technique	3	9
None	1	0
Total	33	48

Source: research survey.

**Table 3.** Confidence interval for the mean estimated endotracheal tube cuff pressure.

	t	df	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
Endo tube cuff pressure (cm H <sub>2</sub> O)	22.65	80	0.000	67.827	61.87	73.79

Source: research survey.



Legend:

■	More than 40 cm H <sub>2</sub> O
■	Between 31 to 40 cm H <sub>2</sub> O
■	Between 20 to 30 cm H <sub>2</sub> O

**Figure 1.** Range of endotracheal tube cuff pressure measured.

pressures were ranged between 25 - 120 cm H<sub>2</sub>O (95 cm H<sub>2</sub>O) for Physician Anaesthetists and 30 - 120 cm H<sub>2</sub>O (90 cm H<sub>2</sub>O) for Nurse Anaesthetists.

*Assessment of VAR (ml) to achieve a cuff pressure of 20 cm H<sub>2</sub>O*

An Independent t-test was used to measure the significant difference of mean volume of air required to achieve a cuff pressure of 20 cm H<sub>2</sub>O for each size of endotracheal tube at 95% Confidence level. The results indicated that the mean volume of air required for endotracheal tube size 7.0 mm was 3.90 ml whilst that for size 8.0 mm was 4.55 ml (Table 5). The difference in mean volume of air required for the two tube sizes was statistically significant (p < 0.006; Table 5).

*Influence of Demographic Characteristics on VAR to achieve a Cuff Pressure of 20 cm H<sub>2</sub>O*

The study adopted Classical Multiple Regression to measure the relationship between demographic variables such as age, weight and height on the volume of air required to obtain a cuff pressure of 20 cm H<sub>2</sub>O.

On regression analysis, the model

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 \tag{1}$$

where  $\beta_0 = -0.089$ ;

$\beta_1 = 0.031$ ;

$\beta_2 = -0.016$ ;

$X_1 = \text{Age (years)}$ ;

$X_2 = \text{Weight (Kg)}$ .

Thus

$$Y = -0.089 + 0.031 (\text{age in years}) - 0.016 (\text{weight in kilograms})$$

where  $Y = \text{VAR}$  to achieve a cuff pressure of 20 cm H<sub>2</sub>O.

The results indicated that age and weight of patients were statistically significant at 95% Confidence level in explaining volume of air required. In contrast, height did not have a statistically significant effect on volume of air required to obtain a cuff pressure 20 cm H<sub>2</sub>O (Table 6).

**Table 4.** Comparisons of endotracheal tube cuff pressure per anaesthetic provider group.

	Group of anaesthesia provider	N	Mean	Std. deviation	Std. error mean	p-value
Endotracheal tube cuff pressure (cm H <sub>2</sub> O)	Physician Anaesthetist	33	65.36	28.073	4.887	
	Nurse Anaesthetist	48	69.52	26.313	3.798	0.499

Source: research survey.

**Table 5.** VAR (ml) to obtain a cuff pressure of 20 cm H<sub>2</sub>O per tube size.

	Size of endotracheal tube	N	Mean	Std. deviation	p-value
Volume of air required to obtain a cuff pressure of 20 cm H <sub>2</sub> O	7.0 mm	40	3.90	1.13	
	8.0 mm	41	4.55	0.95	0.006

Source: research survey.

**Table 6.** Effects of demographic characteristics on VAR to achieve a cuff pressure of 20 cm H<sub>2</sub>O.

Demographic characteristic of patients	Coefficients		t-value	p-value.
	( $\beta$ )	Std. error		
Age	0.031	0.008	3.799	0.000
Weight	-0.016	0.007	-2.420	0.018
Height	0.025	0.014	1.843	0.069

Source: research survey.



## 4. Discussion

The mean endotracheal tube cuff pressure obtained from this study was 67.83 cm H<sub>2</sub>O (**Table 3**). Overall, 93.8% of the mean endotracheal tube cuff pressures measured from this study were above the recommended range of 20 - 30 cm H<sub>2</sub>O (**Figure 1**). This implies that cuff pressures are generally underestimated with the use of estimation techniques of cuff pressure measurement at Korle-Bu Teaching Hospital. This finding agrees with those of earlier comparable studies [14]-[22]. However, the mean cuff pressure obtained in this study is higher than other comparable studies. Palpation of the pilot balloon, 48 out of 81 cases (59.26%), was the most common estimation technique used by anaesthesia providers in Korle-Bu teaching hospital. None of the cases where palpation of pilot balloon was used resulted in normal measured cuff pressures. Thus the palpation of pilot balloon contributed 48 out of 76 cases (63.16%) of the measured cuff pressure which were above the recommended range. This could therefore account for the high pressures measured in this study.

In addition, 6.3% of the cuff pressures measured were within the recommended range of 20 - 30 cm H<sub>2</sub>O (**Figure 1**) as compared to 27% of cases in the study by Sengupta *et al.* [22] and 24% in a study by Ozer *et al.* [23] respectively. The type of estimation techniques which contributed to the measured pressures within the recommended range was the minimal occlusive technique and the predetermined volume technique. However, the estimation methods that achieved optimum cuff pressures with higher percentage accuracy in other studies in literature were not mentioned.

None of the cuff pressures measured was below the recommended range (**Figure 1**) as compared to 23% of cases noted by Sengupta *et al.* [22]. This may suggest that anaesthesia providers at Korle-Bu Teaching Hospital are more likely to underestimate cuff pressures, probably due to excessive precaution against risk of aspiration.

Experienced anaesthesia providers are expected to properly manage endotracheal tube cuff pressures. In this study, it was noted that there was no statistically significant difference in cuff pressures measured between the two groups of anaesthesia providers studied namely Physician anaesthetist and Nurse anaesthetist (p-value = 0.499). This shows that experience does not necessarily confer proper cuff pressure management in the absence of an aneroid manometer. This finding is similar to other comparable studies [22] [25]-[27] but contradicts the findings by Ozer *et al.* [23]. Probably, the attachment of less importance to complications associated with endotracheal tube cuff pressures at Korle-Bu Teaching Hospital may account for the over 90% of measured cuff pressures being above the recommended range. Postoperative follow-up of patients at the hospital after discharge from the recovery ward are done by the surgeons and therefore anaesthesia providers in this hospital are unlikely to discover postoperative complications associated with endotracheal tube cuffs and hence the general trend of poor cuff pressure management.

Although there was no statistically significant difference in cuff pressures between the anaesthesia providers studied, these results reflect the management of endotracheal tube cuff pressure at Korle-Bu Teaching Hospital and the anaesthesia providers studied. This finding might be fairly representative countrywide but variations could exist due to institutional differences in anaesthesia practice.

In this study (**Table 5**), there was a statistically significant difference between the volumes of air required to achieve a cuff pressure of 20 cm H<sub>2</sub>O for tube sizes 7.0 mm and 8.0 mm (p-value = 0.006). This result shows that the inflation volume of endotracheal tube cuff varies as a function of the tube size. This finding, however, disagrees with the outcome of the studies of Sengupta *et al.* [22] but agrees with that of Fernandez *et al.* [9]. However, the study by Fernandez *et al.* was done using an artificial trachea. In this study, however, all females were assigned tube size 7.0 mm as compared to 8.0 mm for males irrespective of their size. In the study by Sengupta *et al.* [22], tube sizes were chosen based on the patient's size. This may account for the difference in the results.

Patient's age and weight had a statistically significant influence in explaining the volume of air required to attain a cuff pressure of 20 cm H<sub>2</sub>O (**Table 6**). Patient's height however, had no statistically significant influence on this volume. If a patient's age was increased by one year, the VAR to obtain a cuff pressure of 20 cm H<sub>2</sub>O would increase by 0.031 ml (p < 0.001, **Table 6**), all other factors remaining constant. Also as the weight of a patient increased by one kilogram, the volume of air required reduced by 0.016ml (p < 0.018; **Table 6**), all other variables remaining constant.

From **Table 7**, a regression equation for the model in calculating the volume of air required to achieve a cuff

**Table 7.** Regression model.

	Coefficient	Std. error	t-value	p-value
Constant	-0.089	2.291	-0.039	0.969

Source: research survey. R<sup>2</sup> = 0.182.

pressure of 20 cm H<sub>2</sub>O was:

$$Y = -0.089 + 0.031(\text{age in years}) - 0.016 (\text{weight in kilograms})$$

where Y = volume of air required to achieve a cuff pressure of 20 cm H<sub>2</sub>O.

Although a significant regression equation for the model was obtained, it was not useful for prediction of the volume needed to achieve a cuff pressure of 20 cm H<sub>2</sub>O as the associated R squared for the model was 0.182. This implies that the prediction of the volume of air required contributed by the age and weight of a patient is only 18.2%.

Anaesthesia providers can however appropriately estimate volume of air required to approximate cuff pressure to 20 cm H<sub>2</sub>O for size 7.0 mm tube for females and size 8.0 mm tube for males using the predetermined volumes obtained from **Table 5**. This can be used in resource limited settings where aneroid manometers for endotracheal tube cuff pressure measurement are absent. This would help prevent complications of inappropriate endotracheal tube cuff pressure management.

The results of this study should be viewed in light of the following limitations. Data for the study was collected at one institution over a period of time, and therefore it is possible that the anaesthesia providers may have changed their endotracheal tube cuff inflation practices because their patients could be included in the study. It was also noticed that the endotracheal tube cuff was mostly inflated by the anaesthetic assistants, and therefore failure on the part of the anaesthetic providers to check the endotracheal tube cuff pressure may wrongly implicate them in poor endotracheal tube cuff pressure management. The aneroid manometer used in the study measured cuff pressures from 0 - 120 cm H<sub>2</sub>O hence cuff pressures above 120 cm H<sub>2</sub>O could not be measured.

## 5. Conclusions

This study revealed that cuff pressures measured by estimation techniques were higher than the recommended range between anaesthesia providers at Korle-Bu Teaching Hospital. Cuff pressures should be routinely measured using a standard manometer so as to reduce complications of high cuff pressures.

The study also revealed no statistically significant difference in the measured cuff pressures between Physician anaesthetist and Nurse anaesthetist at Korle-Bu Teaching Hospital; therefore cuff pressure optimisation has no association with experience of anaesthesia provider. In a large teaching hospital such as the study site, efforts should be made to use aneroid manometers for accurate monitoring of endotracheal tube cuff pressure for optimum patient care. However, in a resource limited setting, endotracheal tube cuff pressures of tube sizes 7.0 mm and 8.0 mm can safely be approximated to the recommended levels with predetermined inflation volumes.

## Competing Interest

The authors have no conflicts of interest to declare, financial or otherwise.

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