ORIGINAL ARTICLE

FREQUENCY OF INAPPROPRIATE ENDOTRACHEAL TUBE CUFF PRESSURE AND ITS VARIABILITY IN PATIENTS UNDERGOING PROLONGED SURGERY: A PROSPECTIVE OBSERVATIONAL STUDY

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Background: Endotracheal tube (ETT) is inserted into the trachea to maintain airway patency. Maintaining adequate ETT cuff pressure is important to ensure a proper seal to lower the risk of aspiration and tracheal trauma. This study was designed to assess the frequency of inappropriate ETT cuff pressure at the time of intubation and variation in ETT pressure at the end of a prolonged surgery. **Methods:** This study was conducted in the Department of Anaesthesiology, Aga Khan University from October 2019 to March 2020. All adult patients of both genders, undergoing prolonged surgery under general anaesthesia were included. Patients were intubated with an appropriate size ETT, and the cuff was inflated with air. ETT cuff pressure was measured after intubation and, at the end of prolonged surgery to assess any variation. **Results:** Fifty-eight patients were included, of which 37 (63.8%) were female. The mean age was 47.36 years. The frequency of inappropriate ETT cuff pressure at the time of intubation was found in thirty-five (60.3%) patients, which was corrected to 25 cm H_2O before the start of surgery. At the end of the surgery, forty-one (70.7%) patients showed an increase in ETT cuff pressures with the majority (33%) having a variation of 51–70 (81–100 cm H_2O). **Conclusion:** The frequency of inappropriate ETT cuff pressure at the time of intubation was found in thirty-five (60.3%) patients. In six (10.3%) patients, ETT cuff pressure was below 20 cm H_2O while in twenty-nine (50%) patients, ETT cuff pressure was above 30 cm H_2O. In forty-one (70.7%) patients ETT cuff pressure was abnormally high that is >30 cm H_2O at the end of prolonged surgical procedures.

Keywords: General anaesthesia; Endotracheal tube; Intraoperative monitoring; Cuff pressure; Prolonged surgery

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INTRODUCTION

Endotracheal intubation is putting a plastic tube called the endotracheal tube (ETT) into the airway to serve as a channel to administer gases and anaesthetic agents.[1,2] The most common route is orotracheal, where an ETT is passed through the mouth and larynx into the trachea.[3,4] After the ETT placement, a balloon cuff is inflated to secure it in place, prevent leakage of gases, and protect the airway from gastric contents.[5,6] The tube is then secured to the face and connected to the anaesthesia machine through a breathing circuit.[7,8]

Endotracheal tube cuff pressure has a lot of significance in airway management.[9,10] As recommended, the adequate range of ETT cuff pressure is from 20 to 30 cm H_2O.[11,12] Gilliland *et al.* reported that only 18.75% of intubated patients had ETT cuff pressures within the normal range of 20–30 cm H_2O.[6] It has also been reported that ETT cuff pressure may increase during prolonged surgical procedures or be inadequate during intubation, if not measured correctly by an aneroid manometer.[13] Inappropriately inflated ETT cuff may result in postsurgical morbidity. If the cuff pressure is higher than normal, it may cause tracheal injury, and if below the normal range, can result in inadequate seal and an increased risk of gastric content aspiration. Gilliland *et al*. demonstrated that the ETT cuff pressures in 64.58% of the patients were higher than the acceptable upper range of 30 cm H_2O.[13]

In clinical practice, ETT cuff inflation is undertaken by estimation techniques, and the chances of inadequate cuff pressure are high.[14,15] There is a need to apply accurate methods to ensure a proper seal is maintained at intubation and throughout the surgery to prevent intraoperative morbidity.[16] Limited studies have explored the role of ETT cuff pressure monitoring intermittently during surgery, especially in prolonged surgery and surgery under prone positioning to prevent airway morbidity and postsurgical outcomes.[9]

The rationale of this study was to assess ETT cuff management practices, and cuff pressure measurement after intubation and at the end of a prolonged surgery. The primary objective of this study was to evaluate the frequency of inappropriate endotracheal tube cuff pressure just after intubation. The secondary objective was to assess variation in endotracheal cuff pressure at the end of prolonged surgery.

MATERIAL AND METHODS

This prospective observational study was carried out from October 2019 to March 2020 in the Department of Anaesthesiology, The Aga Khan University, after the approval from Institutional Ethical Review Committee. All adult patients of both genders, between 20–70 years of age, scheduled for prolonged elective operations (>3 hours), under the supine position with an ASA physical status of I, II, or III were included. The inclusion of patients was done once the operative procedure was finalized and informed consent was taken in the pre-operative area. Those who did not consent, and those with anticipated difficult intubation, undergoing any oral or airway surgical procedures or laparoscopic surgical procedures were excluded from this study.

Data collection was carried out using a specially designed proforma which included the patient's demographics, diagnosis, surgical procedure, and its duration, ETT cuff pressure after intubation, and at the end of surgery. Variation in cuff pressure was calculated by noting the difference in cuff pressure of ETT at the time of intubation and at the time of the skin closure and was considered inappropriate if lower or higher than the normal range of 20–30 cm of H_2O.

All patients were induced and intubated by the primary anaesthesia team using the standard technique with the appropriate size of ETT. After general anaesthesia and intubation, the ETT cuff was inflated with air by an anaesthesia technician to achieve a seal, subjectively. ETT Cuff pressure was observed and recorded with a manometer by the primary anaesthetist. ETT cuff manometer, Portex Germany was used for cuff pressure measurement. The range of this manometer was from 0–120 cm H_2O. If cuff pressure was not between 20–30 cm H_2O, it was corrected to a pressure of 25 cm H_2O (optimal pressure) by using an aneroid manometer.

The second measurement of ETT cuff pressure was observed and recorded with a manometer at the end of the operation (just after skin closure) before giving a reversal agent by the primary anaesthetist. ETT cuff pressure variation was calculated as the difference between ETT cuff pressure at the end of surgery minus at the time of intubation that is the start of surgery (ETT cuff pressure end – the start of surgery). If the difference is positive this means an increase in ETT cuff pressure.

All statistical analyses were performed using statistical packages for social science version 19 (SPSS Inc., Chicago, IL). Mean and standard deviation was computed for quantitative variables like age, weight, height, BMI, and duration of surgery. Frequency and percentage were estimated for qualitative variables like gender, co-morbid (e.g., Hypertension, Diabetes Mellitus), size of ETT, endotracheal tube cuff (Appropriate/Inappropriate pressure), and Nitrous oxide used.

RESULTS

A total of fifty-eight patients were included in this study, of which 37 (63.8%) were female and 21 (36.2%) were male. The mean age of patients was 47.36 (±12.84) years, and the mean weight was 71.06 Kg. The mean BMI was 28.36 Kg/m^2. Most of the patients belonged to the ASA physical status class II (58.6%), shown in Table 1. The most common comorbidity was hypertension (22.4%) followed by diabetes (20.7%). The mean duration of surgery was 261.16 minutes (4.35 hours) and the surgical procedure included was Supratentorial Craniotomy, laparotomy, mastectomy, and others. Nitrous oxide was used in the majority of the patients undergoing GA (79.3%), mostly at a concentration of 51–60% (50%). Most of the male patients were intubated with a size 8.0 ETT and female patients with a size 7.5 ETT for adequate ventilation.

The frequency of inappropriate ETT cuff pressure at the time of intubation was found in thirty-five (60.3%) patients. In six (10.3%) patients, ETT cuff pressure was below 20 cm H_2O while in twenty-nine (50%) patients, ETT cuff pressure was above 30 cm H_2O, as shown in Figure-1. In the male patients, 66.7% had inappropriate ETT cuff pressure while female patients had 56.8% inappropriate cuff pressure. In patients with a BMI of more than 30 Kg/m^2, 71.4% of patients had inappropriate ETT cuff pressure at the time of intubation. Different sizes of ETT were used in surgical procedures. The lower size was used in female patients (like 6.5, 7.0 & 7.5 mm I.D) while in male patients, 7.5 and 8.0 mm I.D size was used. The frequency of inappropriate ETT cuff pressure at the time of intubation was highest in those intubated with size 8.0 mm ID.

ETT cuff pressure at the end of prolonged surgery was higher than at the time of induction (>30 cm H_2O) in forty-one (70.7%) of the patients. Seven (12%) patients showed an increase of 6–30 (31–60 cm H_2O), Nine (15.5%) patients had an increase of 31–50 (61–80 cm H_2O), nineteen (32.8 %) patients had an increase of 51–70 (81 to 100 cm H_2O) and six (10.3%) patients had an increase of more than 70 (>100 cm H_2O). Only four (6.9 %) patients had a decrease in ETT cuff pressure, (between 1–5 cm H_2O) but it was not below the lower range of 20 cm H_2O. No patient had less than normal ETT cuff pressure (<20 cm H_2O) at the end of prolonged surgery as shown in Figure-2.

Nitrous oxide was used in 79.3% of cases. The median percentage of nitrous oxide used was 57.5%. Out of which 40–50% of nitrous oxide was used in 47.8% of cases, 51–60% was used in 50% of cases, and more than 60% was used in 2.2% of cases. The mean duration of nitrous oxide was 266.38 minutes, and the range is 180–420 minutes. Patients who received nitrous oxide had an incidence of increased ETT cuff pressure

of 89.1% at the end of prolonged surgical procedures while patients who did not receive nitrous oxide had normal ETT cuff pressure at the end of prolonged surgical procedures.

Table-1: Demographic characteristics and ASA physical status of patients (n=58)

Variables	Point Estimates
Age (Years)	
Mean±SD	47.36±12.84
Weight (kg)	
Mean±SD	71.06±14.11
Height (cm)	
Mean±SD	159.89±8.49
BMI (kg/m2)	
Mean±SD	28.36±8.35
Gender	
Male	21 (36.2%)
Female	37 (63.8%)
ASA Physical Status	
ASA-I	9 (15.5%)
ASA-II	34 (58.6%)
ASA-III	15 (25.9%)

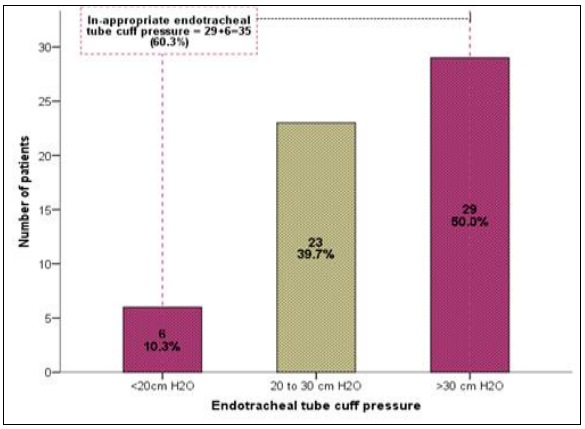

Figure-1: Frequency of inappropriate endotracheal tube cuff pressure just after intubation (n=58)

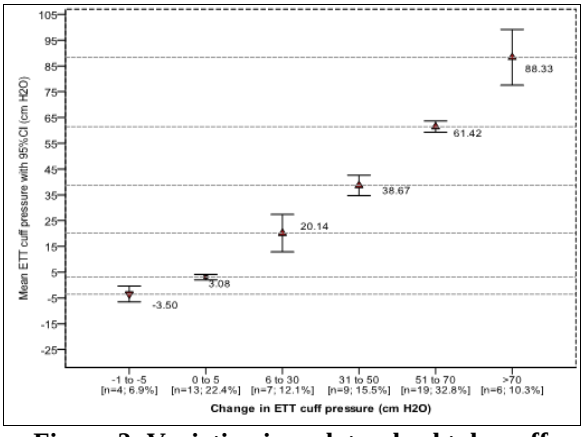

Figure-2: Variation in endotracheal tube cuff pressure measurement at the end of surgery [n=58]

DISCUSSION

This study showed the frequency of inappropriate ETT cuff pressure at the time of intubation in thirty-five (60.3%) patients and inappropriate ETT cuff pressure at the end of the prolonged surgical procedure in forty-one (70.7%) patients. The objective monitoring of ETT cuff pressure by manometer is important in clinical practice to avoid morbidity related to the higher or lower inflation pressure of the cuff.[17] ETT cuff pressure is considered higher when the cuff pressure is more than the perfusion pressure of the tracheal mucosa, which is over 32 cm H_2O. An ETT cuff pressure is considered lower when the cuff is unable to seal the trachea, which is less than 20 cm H_2O.[18]

Literature showed that in 44% of the patients, ETT cuff pressure was observed within the normal range of 20 to 30cm H_2O. In this study, 39.7% of the patients had cuff pressures within the normal range of 20–30 cm H_2O at the time of intubation and 29.3% at the end of the prolonged surgical procedure.

The current practice of assessing ETT cuff pressure in the operating room is by the subjective feeling of anaesthesia providers by the palpatory method.[19] This method is an approximate estimation of cuff pressure. The estimation techniques include minimal occlusive volume technique, minimal leak technique, and palpation technique.[20] Totonchi *et al.* recommended the minimal occlusive volume technique compared to the palpation technique to reduce the incidence of tracheal stenosis.[21]

Stewart *et al.* compared ETT cuff inflation by the anaesthesia provider using estimation techniques with objective measurements by a manometer. They demonstrated that 65% of the providers achieved pressures higher than 40 cm H_2O and only 30% achieved pressures within the normal range. They recommended that a manometer should be used because the estimation technique is not reliable.[21] In this study, approximately 40% of patients had cuff pressure within the normal range at the time of intubation.

Sengupta *et al.* measured ETT cuff pressures sixty minutes after intubation with a pressure manometer. They showed that in only 27% of patients, cuff pressure was within the acceptable range. The mean cuff pressure was 35.3 cm H_2O: in 50% of patients. the cuff pressure was more than 30 cm H_2O; in 27% of the patients, cuff pressure was more than 40 cm H_2O, and in 23% of the patients, the pressure was less than 20 cm H_2O. They recommended that cuff pressures should be optimized after intubation and assessed objectively with a manometer.[22]

In this study, ETT cuff pressure during prolonged surgical procedure was within the normal range (20–30 cm H_2O) in 29.3% of patients, (6.9% of patients had a mean difference of -3.50 cm H_2O, 22.4 % of patients had a mean difference of 3.08 cm H_2O). While 70.7% of patients had variation in the abnormal range in ETT cuff pressure during the prolonged surgical procedure.

Regular use of a manometer to record ETT cuff pressure has been shown to reduce the frequency of airway-related morbidity after the operation. Liu *et al*. showed an incidence of 4% blood-streaked expectoration, 3% hoarseness, and 34% sore throat.[23] 11.4% decrease in the incidence of ventilator-related morbidity with the use of a manometer compared to 16.3% with the minimal leak test technique.[24] Post-operative airway complications contribute to the additional cost to care and affect the quality of anaesthesia services and in turn, reduced patient satisfaction.[25]

Gilliland *et al*. found that 64.58% of patients have abnormally high ETT cuff pressures (above 30 cm H_2O). They recommend objective measurement of cuff pressures with a manometer.[13] In this study, patients who received nitrous oxide had an incidence of increased ETT cuff pressure of 89.1% at the time of extubating during a prolonged surgical procedure while Patients who did not receive nitrous oxide had normal ETT cuff pressure at the time of extubation during the prolonged surgical procedure. A single observation of the ETT cuff pressure value may lead to patient-related adverse effects. Hockey *et al*. recommended that the objective device should be used intermittently to optimize cuff pressure.[26]

Kako *et al*. reported the variation in the intraoperative cuff pressure compared to the baseline in the range of -25.8 to +16.3 cm H_2O in 30% of patients, the decrease of the intracuff pressure was ≥10 cm H_2O in 20% of patients the increase of the cuff pressure was ≥10 cm H_2O in 17% of patients. All patients showed variations in the intracuff pressure throughout the surgery.[27] There is a lack of awareness about objective assessment of cuff pressure among healthcare staff. Abubaker *et al*. reported that only 30.67% of participants (physician and staff) had prior knowledge about the ETT cuff manometer and 73.33% had never used a manometer. 28.0% of physicians and staff know about the morbidity associated with inappropriate ETT cuff pressure.[28] Kumar *et al*. demonstrated the desirable effects of using continuous in-built intracuff pressure measurement techniques during anaesthesia.[29]

Care should be taken during ETT cuff pressure monitoring because frequent measurements may cause a drop in the cuff pressure, if not properly done. Xiang *et al*. recommended modified ETT cuff pressure measurement methods to monitor ETT cuff pressure by attaching it to the three-way tap and pressurizing it to the desired pressure that is 25 to 30 cm H_2O and then moving the tap.[30]

The ETT cuff pressure may be influenced by different factors, like environmental factors (high airway pressure, use of nitrous oxide, duration of surgery, type of procedure, and altitude), patient factors (position of head, neck, and body) ETT cuff related factors (type of cuff), and use of muscle relaxant, and body temperature. Intermittent assessment of ETT cuff pressure is recommended for routine clinical practice in all intubated patients.[31]

Strengths of the study:

This study includes a local population-based sample that represents low and middle-income countries (LMIC). It may contribute as a reference for future research in the LMIC. The results of the study will help us to know the frequency of inappropriate ETT cuff pressure and may help in making institutional guidelines for the appropriate management of ETT cuff pressure during prolonged surgical procedures under general anaesthesia.

Limitations of the study:

Study results were based on small sample size and are limited to one center only. Including multiple centers, would have given a more holistic view of the overall practice of ETT cuff pressure measurement and morbidity associated with inappropriate cuff pressure. Another limitation could be the lack of statistical comparisons, lack of a rigorous method to identify risk factors (of inadequate ETT cuff pressure) such as logistic regression, and the measurement of ETT cuff pressure at the end of surgery not at a fixed point of time duration.

Recommendations

The management of ETT cuff pressures is important during anaesthesia, especially during prolonged operations. This would prevent morbidity related to the over-inflation and under-inflation of the ETT cuff. This study recommends the routine use of ETT cuff pressure manometer in every surgical procedure. ETT cuff pressure should be measured at the time of intubation and at frequent intervals, especially during prolonged surgical procedures.

If we create awareness about the significance of ETT cuff pressure monitoring than we could minimize the hazards caused by inappropriate ETT cuff pressure in patients.

CONCLUSION

The frequency of inappropriate endotracheal tube cuff pressure at the time of intubation was found in thirty-five (60.3%) patients. In six (10.3%) patients, ETT cuff pressure was below 20 cm H_2O while in

twenty-nine (50%) patients, ETT cuff pressure was above 30 cm H_2O.

Endotracheal tube cuff pressure at the end of prolonged surgical procedure was within the normal range of 20 to 30 cm H_2O, in seventeen (29.3%) patients, while in forty-one (70.7%) patients ETT cuff pressure was abnormally high that is >30 cm H_2O.

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Declaration of patient consent:
The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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There are no conflicts of interest.

AUTHORS' CONTRIBUTION

MFRS: Concept, design, literature search, data acquisition and analysis, manuscript preparation, editing and review. ASS: Concept, design, manuscript editing and review.

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