ORIGINAL ARTICLE

Achieving an optimal Endotracheal Tube Pressure: Comparison of Loss of Resistance and Pilot Balloon Techniques

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ABSTRACT

Background: Inappropriate estimation of endotracheal tube pressure can result in significant harm to the patient, and the use of a manometer is the only reliable way of ensuring an optimal pressure range (20-30cmH2O). In the absence of a manometer, the Pilot balloon palpation (PBP) technique is commonly employed in our environment. **Aim**: This study compared the accuracy of a newer method of ETTc inflation called passive release technique using loss of resistance (LOR) syringe with the PBP technique in determining optimal ETTc pressure. **Methods**: One hundred and eighty ASA I and II patients, aged 18 – 65 years, scheduled for elective procedures under general anesthesia with ETT were randomized into 2 groups with one group having their cuff pressures measured by pilot balloon palpation (PBP) and the other using a loss of resistance syringe (LOR). The cuff pressure was then measured in each group using a sensitive manometer. **Results**: The mean ETTc pressure was found to be significantly higher in the PBP group than in the LOR group (64.28 ± 31.12 and 29.64 ± 11.68; p= 0.0001). The LOR technique was found to be significantly more accurate in ETTc pressure estimation than the PBP techniques (59.3 vs 27.8%; p = 0.0001). **Conclusion**: Passive release technique using LOR was found to be significantly more accurate compared to PBP in optimal ETTc pressure estimation.

Key words: Endotracheal tube cuff pressure, pilot balloon palpation, loss of resistance syringe.

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Introduction

Endotracheal intubation has grown to be a common airway maintenance technique in patients undergoing general anaesthesia, and this is often accompanied by ETT cuff inflation. The main functions of the ETTc inflation are the provision of an adequate seal for positive pressure ventilation and the prevention of aspiration.

The tracheal mucosa is made up of a highly pressure-sensitive, pseudostratified, ciliated epithelium.

Upon ETTc inflation, the tracheal mucosal perfusion depends on the gradient between its perfusion pressure (27-40cmH_2O) and the ETTc pressure.[1,2]

Once the ETTc pressure exceeds the mucosal perfusion pressure, ischaemic and necrotic changes may occur.[1] thus resulting in post anaesthesia complications like sore throat, cough. Studies have shown that more than 50% of patients may develop sore throat within 24hrs of extubation.[3,4]

Conversely, an underestimation of ETTc pressure subjects the patient to the risk of aspiration of either

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stomach content or secretions. This underscores the need for an optimal ETTc pressure.

Historically, the first intubation of the larynx for anaesthetic management dated as far back as 1878, when Sir William McEwen of Glasgow described his attempt at orotracheal intubation on patients undergoing head and neck surgeries.[5] In the United States alone, over 20 million endotracheal intubations are performed yearly.[6]

The ETTc has evolved since its introduction into practice in the twentieth century from the first generation low-volume, high-pressure to the second generation high-volume, low-pressure type. Regardless of the type of cuff, the recommended ETTc pressure is 20-30cmH_2O[7,8] and the gold standard of measurement is the use of a manometer throughout the intubation.[1] This is because the cuff pressure may change over the intubation period.[9,10] However, this is not the common practice, especially in resource-poor settings like ours where the manometer is expensive and not readily available.[6]

Various inflation techniques are employed in order to attain the recommended 20-30cm$H_2$0. These include minimal occlusive volume (MOV), minimal leak technique (MLT), predetermined volume of air (PVA), pilot balloon palpation (PBP), and more recently the Passive Release Technique. However, none of these techniques have proven accuracy comparable to the use of a manometer.[11]

The commonly used PBP entails the use of air drawn into a 10 or 20ml syringe to incrementally inflate the ETTc while simultaneously palpating the pilot balloon for fullness. Anaesthetists use the level of fullness of the pilot balloon to estimate the ETTc pressure. Although commonly used in our environment, PBP is subjective, observer-dependent and found to be ineffective in predicting the ETTc pressure.[12] Studies have shown that fewer than 25% of patients recorded cuff pressure within the safe range, regardless of the experience of the anaesthetist.[12,13]

The passive release technique, a new inflation method, has been shown to be more effective in achieving optimal cuff pressure. It entails inflation of the ETTc to its maximum capacity at once using a syringe, and then allowing the plunger to recoil passively. The point at which the plunger stops corresponds to the required ETTc pressure and this can be achieved using a 20ml disposable syringe, epidural pulsator syringe and a loss of resistance (LOR) syringe which has been shown to achieve the recommended ETTc pressure in more than 60% of patients.[12]

This study was aimed at comparing the accuracy of the passive release technique using the LOR syringe to the traditionally used PBP method in estimating the ETTc pressure in patients undergoing general anaesthesia with orotracheal intubation in our setting.

Methods

This was a prospective, double-blind, randomized study carried out at Aminu Kano Teaching Hospital, a tertiary institution in Northwest Nigeria. With institutional ethical committee approval obtained, 180 patients aged between 18 and 65 years who belonged to the American Society of Anaesthesiologist (ASA) physical status classification I and II and had given written consent were recruited into this study. These patients were scheduled for elective surgical procedures under general anaesthesia with orotracheal intubation, in urology, orthopaedics, plastic, gynaecology and general surgery. Patients excluded from this study include; head and neck surgeries, obstetric patients, any patient considered having a full stomach, patients with preexisting airway symptoms, patients expected to remain intubated beyond the operating room, surgical procedures in a prone position, and patients with an anticipated difficult airway. Patients enrolled for the study were randomly allocated into either group PBP (pilot balloon palpation) or LOR (loss of resistance) comprising of 54 patients each after picking one folded sheet of paper from a box containing uniformly folded pieces of paper labeled either PBP or LOR. The paper was handed over to the research assistant (a designated resident doctor) who was not blinded to the study group the patient belonged to and was not involved in data collection. The investigator was not notified of the group allocation of the patients.

Eligible patients were reviewed a day before surgery. History, physical examination, including mouth opening and Mallampati score, and review of investigation results (such as complete blood count, electrolytes, urea, and creatinine) were carried out. The patient's age, sex, weight, height, BMI, and neck circumference were recorded, and preoperative fasting was ensured.

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On arrival in the operating room, routine baseline vital signs which include non-invasive Systolic and Diastolic blood pressures (SBP and DBP), Mean Arterial blood pressure (MAP), Pulse rate (PR), Respiratory rate (RR), peripheral arterial oxygen saturation of Hemoglobin (SPO_2) and Electrocardiograph were obtained. Intravenous access was secured with a size 16G or 18G (wide bore) cannula and 0.9% saline infusion commenced.

The patient was preoxygenated with 100% oxygen, and induction of anaesthesia was achieved with 2mg/kg intravenous propofol or 5mg/kg intravenous sodium thiopentone attaining loss of consciousness as evidenced by loss of verbal contact or eyelash reflex respectively. After test ventilation, 0.5mg/kg iv atracurium or 0.1mg/kg iv pancuronium was administered, and ventilation was assisted for 3 to 5min to allow for the onset of action. Direct laryngoscopy using Macintosh laryngoscope with size 3 or 4 blades was carried out followed by intubation with appropriately sized (sizes 7.5 - 8.0mm and 7.0 - 7.5mm internal diameter for male and female patients respectively) endotracheal tube. The duration of laryngoscopy and the number of intubation attempts were documented. Inflation of the cuff was carried out by the attending anaesthetist based on the study group the patient was assigned to. In the PBP group, the attending anaesthetist used a 10ml syringe (BD discardit II), fully filled with air, to inflate the cuff via the pilot balloon to a level he or she considered adequate by palpation of the pilot balloon. The syringe was detached and hidden away by a research assistant, the anaesthesia provider/researcher was then invited by the research assistant after ETTc inflation had been completed to measure and record the pressure using a cuff manometer. The measurement was carried out with the patient's head in a neutral position. The researcher was unaware of the technique of ETTc inflation used. In the LOR group, the attending anaesthetist used an air-filled 10ml plastic, leur slip, loss of resistance syringe (Halyard Health, Belgium), to inflate the balloon to the maximum it could accommodate, and then released the plunger for passive recoil until it ceased, which was regarded as the endpoint. The loss of resistance syringe was then disconnected and hidden away by a research assistant who invited the researcher into the induction room to measure and record the ETTc pressure using the manometer, with the patient's head at a neutral position. The researcher was unaware of the technique of ETTc inflation used.

In both groups, very high and very low pressures were adjusted as was done in the Bulama et al study.[12] In patients where ETTc pressure was below $20cmH_2O$, it was adjusted to $25cmH_2O$ using the manometer. On the other hand, high cuff pressures beyond $50cmH_2O$, it was reduced to $40cmH_2O$.

At the end of the pressure measurement in both groups, the manometer was detached and the ETT connected to the breathing circuit, and ventilation was started. Anaesthesia was maintained with 1-2 MAC of isofluranein33% oxygen-air mixture. Analgesia was achieved with 2 microgram/Kg of intravenous fentanyl. Top-up boluses of 1 microgram/Kg were given every hour. Muscle relaxant was reversed with neostigmine 2.5 mg and atropine 1.2 mg at the end of surgery

The proportion of patients whose ETTc pressure fell within the recommended range among the passive release technique and the pilot balloon palpation techniques were recorded on a data form and the data obtained was analyzed using Statistical Package for Social Sciences (SPSS) version 21.0. Quantitative variables such as age, weight, height, neck circumference, and duration of intubation were summarized using mean (± standard deviation) and compared using an independent t-test. Qualitative variables such as the proportion of optimal ETTc pressure in the two groups were summarized using percentages and compared using the Chi-squared test or Fisher's exact test where applicable. Level of statistical significance was set at a p-value of <0.05.

Results

A total of 108 patients were recruited for this study over a period of 6 months. The mean age of the patients in the PBP and LOR groups were 39.34 ± 13.9 and 38.24 ± 13.8 years respectively (p = 0.702). Other demographic profiles and clinical characteristics of the patients in the two study groups were also comparable as shown in **table I**. There were no statistically significant differences between the two groups with respect to age, sex, ASA classification, Mallampati, mean neck circumference and BMI distribution.

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TABLE I: Comparison of Patients' Demographic data and Clinical Characteristics

	Group PBP (n = 54)	Group LOR (n = 54)	p-value
Age (years)	39.34 ± 13.90	38.24 ± 13.80	0.702
Neck circumference(cm)	34.16 ± 1.58	34.34 ± 2.48	0.644
BMI (kg/m²)	24.21 ± 4.9	25.65 ± 5.13	0.142
Gender (Male:Female)	25:29	21:33	0.436
ASA (I:II)	30:24	28:26	0.847
Mallampati	40:14	36:18	0.399

There was a statistically significant difference in mean ETTc pressure between the two study groups as indicated in **table II**, with the PBP group having the higher pressure (64.28 ± 31.12 vs 29.64 ± 11.68 cmH_2O, p = 0.0001). There was also a statistically significant difference in the accuracy of ETTc inflation pressure between the two groups. Normal ETTc pressure was recorded in 32 (59.3%) patients in LOR group compared to 15 (27.8%) in the PBP group (p = 0.0001). While none of the patients in the PBP group had low ETTc pressure, 10 (18.5%) of the patients in the LOR group had their cuff pressure below normal. Up to 39 (72.2%) patients in the PBP group recorded high ETTc pressure compared to only 12 (22.2%) in the LOR group.

TABLE II: Comparison of mean ETTc pressure characteristics and proportion of patients based on ETTc inflation pressure categories between the two study groups

	Group PBP (n = 54)	Group LOR (n=54)	X^2value	p-value
Mean ETTc Pressure (cmH_2O)	64.28 ± 31.12	29.64 ± 11.68		0.0001*
ETTc Pressure Category				
LOW (<20)	0 (0%)	10 (18.5%)		
NORMAL (20-30)	15 (27.8%)	32 (59.3%)	30.44	0.0001*
HIGH (> 30)	39 (72.2%)	12 (22.2%)		

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Discussion

The results from this study have shown that 59.3% of patients had normal ETTc pressure in the LOR group as compared to only 27.8% in the PBP group. This has demonstrated the superiority of the Passive Release technique using Loss of Resistance Syringe over the Pilot balloon Palpation technique in achieving the recommended ETTc pressure.

Bulamba et al.[12] also compared the PBP and LOR techniques and found a similar trend of results as in this present study, 66.3% of their patients had normal ETTc pressure while using the LOR technique compared to only 22.5% with the PBP method ($p < 0.01$). Their LOR group had slightly higher numbers than ours possibly because they used a smaller-sized syringe (7ml) compared to the 10ml syringe used in this study. Huh et al.[14] in their study had found a significantly higher proportion of optimal ETTc pressure using a 10ml syringe compared to a 20ml syringe by the passive release technique, $p < 0.05$. This could be because the smaller syringe, having a lighter weight plunger, may give better chance for equilibration of the transmitted pressure from the balloon.

The different ranges of recommended ETTc pressure employed among researchers while comparing cuff inflation techniques have led to a disparity in outcomes, Cho et al[15] used 16-40 cmH_2O as their recommended range and recorded a 100% accuracy of ETTc inflation with the LOR technique compared to only 16.7% in those patients who had PBP technique, likewise, Huh et al[14] found 63.2 % of their patients having ETTc pressure within the chosen range of 25-40 cmH_2O using the Passive Release Technique with 10ml conventional syringe in a simulation study using tracheal models. These chosen ranges in both studies were wider than that in the present study (20-30cmH_2O) which could account for the differences.

Our choice of an ETTc pressure range of 20-30cmH_2O was informed by the fact that it is above the critical point for risk of aspiration (20 cmH_2O) and below the perfusion pressure of the tracheal mucosa (27-40 cmH_2O).[16] thus protecting the patients from the risk of aspiration as well as that of mucosal ischaemia and its attending complications

A contrary finding to our study was however reported by Kim et al.[17] They found optimal ETTc pressure in only 7.5% of patients in their LOR group and 22.5% in patients whom PBP was used for. However, their study was carried out in the emergency room on patients that were likely unstable, and emergency situation is known to be associated with panic among attending physicians and thus might have affected their results.

This study has re-emphasized that the use of PBP method of ETTc pressure estimation, although commonly employed in operating theaters does not offer an optimal ETTc pressure range (20–30cmH_2O)

Conclusion

We conclude that the Passive Release Technique using the Loss of resistance syringe is significantly more accurate than the Pilot Balloon Technique in the estimation of ETTc pressure.

Recommendation

Use of endotracheal tube cuff manometer should be encouraged to ensure optimal ETTc pressure in order to prevent complications that may result from inappropriate cuff inflation. Where a manometer is not readily available, the passive release technique using LOR should be used because it is superior to the PBP technique in achieving the optimal ETTc pressure.

Conflict of Interest

We declare no conflict of interest

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