

Endotracheal tube cuff pressures in adult patients undergoing general anaesthesia in two Johannesburg academic hospitals

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Background: Endotracheal tube (ETT) cuff pressure commonly exceeds the recommended range of 20–30 cm H₂O during anaesthesia. A set volume of air will not deliver the same cuff pressure in each patient and the pressure exerted by the ETT cuff can lead to complications, with either over- or under-inflated cuffs. These can include a sore throat and cough, aspiration, volume loss during positive pressure ventilation, nerve palsies, tracheomalacia and tracheal stenosis. No objective means of ETT cuff pressure monitoring is available in the operating theatres of Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Chris Hani Baragwanath Academic Hospital (CHBAH). The ETT cuff pressure of patients undergoing general anaesthesia is therefore unknown.

Method: ETT cuff pressure of 96 adult patients undergoing general anaesthesia without nitrous oxide at CMJAH and CHBAH was measured by one researcher. A RUSCH Endotest™ manometer was used to measure ETT cuff pressure in size 7.0 – 8.5 mm ETTs. The cuff inflation technique that was used by the anaesthetist was also documented.

Results: The mean ETT cuff pressure recorded was 47.5 cm H₂O (range 10–120 cm H₂O). ETT cuff pressures exceeded 30 cm H₂O in 64.58% of patients. Only 18.75% of patients had ETT cuff pressures within the recommended range of 20–30 cm H₂O. There was no statistically significant difference between the ETT cuff pressures measured at the two hospitals. Minimal occlusive volume was the most frequent technique used to inflate the ETT cuff (37.5%); this was followed by inflating the ETT cuff with a predetermined volume of air in 31.25% of cases and palpation of the pilot balloon (27.08%). There was no statistically significant difference between the ETT cuff pressure measured and the inflation technique used by the anaesthetist.

Conclusion: ETT cuff pressures of the majority of patients undergoing general anaesthesia at two academic hospitals were higher than the recommended range. ETT cuff pressure should routinely be measured using a manometer.

Keywords: adults, endotracheal tube cuff pressures, general anaesthesia, manometer

Introduction

Endotracheal intubation plays an integral role in anaesthesia. The main function of the endotracheal tube (ETT) cuff is twofold: to limit air leakage during positive pressure ventilation (PPV) and to prevent aspiration of gastric content, by creating a seal between the patient's trachea and the cuff.¹ ETT cuffs have evolved since they were introduced commercially in the twentieth century from first-generation, low-volume, high-pressure cuffs made from rigid material (reusable rubber), to high-volume, low-pressure cuffs made from softer more malleable and disposable material.^{1,2} Today ETTs have highly compliant, high-volume, low-pressure cuffs usually made of polyvinyl chloride (PVC) (50–80 micron) as it is nontoxic, smooth, transparent and inexpensive. These ETTs also have thermoplastic properties and conform to the patient's anatomy at body temperature.² High-volume, low-pressure cuffs can adapt easily to the varying shapes of the trachea but can increase the incidence of aspiration when folds, acting as micro-channels, are formed in the excess material of the cuff.¹

The pressure exerted on the tracheal mucosa by the ETT cuff should be as low as possible to avoid complications from obstructing tracheal mucosal blood flow but high enough to form an effective seal when delivering PPV. Tracheal perfusion pressure, estimated to be 22 mm Hg to 30 mm Hg, must not be exceeded by the ETT cuff pressure. Tracheal injury with pathological changes begins when ETT cuff pressure exceeds the capillary blood pressure supplying the trachea and is followed by ischaemia with inflammation. If not relieved this can lead to mucosal necrosis, ulceration, granulation and the

formation of scar tissue leading to stenosis.^{1,4} High-volume, low-pressure cuffs can reach a diameter one and a half to two times that of an average adult human trachea when fully inflated. They may therefore be associated with a sore throat due to large mucosal contact area.³ Sore throat and cough are common complaints in patients undergoing general anaesthesia with endotracheal intubation.

A critical first step towards patient safety is inflating the ETT cuffs to pressures that will not lead to tracheal morbidity. Various ETT cuff inflation techniques are commonly used to inflate ETT cuffs in the absence of an accessible measuring device. These include minimal leak technique (MLT), minimal occlusive volume (MOV), inflating the cuff with a predetermined volume of air (PVA) and palpation of the pilot balloon as a guide for the quantity of air needed to inflate the cuff.¹ However, these can lead to over- or under-inflated ETT cuffs with associated complications and only a manometer gives an objective reading.

Both international^{5,6,8} and local⁷ literature has shown that ETT cuff pressure during anaesthesia commonly exceeds the maximum recommended pressure of 30 cm H₂O.

The aim of this study was to determine the ETT cuff pressures of patients receiving general anaesthesia at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Chris Hani Baragwanath Academic Hospital (CHBAH) and to document the cuff inflation techniques that were used to achieve these pressures.

Method

Approval to conduct this prospective study was obtained from the relevant authorities including the Human Research Ethics Committee (Medical) of the University of the Witwatersrand. Deferred, informed, written consent was obtained from the study participants. Informed, written consent to measure the ETT cuff pressure was obtained from the anaesthetist in charge of the patient.

Adult patients who presented to the operating theatres of CMJAH and CHBAH for surgery under general anaesthesia administered with a cuffed ETT were included in this study. In consultation with a biostatistician a sample size of 96 was calculated using the Stat Calc function of Epi Info™ (CDC, Atlanta, GA, USA). This was based on an expected frequency of 45% of ETT cuff pressures being greater than 30 cm H₂O. The expected frequency was obtained by using data based on previous international^{5,6,8} studies that measured ETT cuff pressures during anaesthesia. A 10% precision and 95% confidence level was used to calculate the sample size.

ETT cuff pressures were measured at the convenience of one researcher (LG) over an extended period of time (October 2011 to December 2013). Data were collected at CHBAH and CMJAH on weekdays during normal working hours (07:30–17:00). Theatres where emergency surgery as well as elective general, vascular, plastic, orthopaedic, gynaecological and urological surgery took place were used. The ETT cuff pressure measurements of any one intubating anaesthetist were not included more than three times in

this study; and cuff pressure measurements from the same anaesthetist was not used consecutively or more than once on the same day. This, in conjunction with the extended data collection time, limited data contamination. Patients were excluded if they were intubated before arriving in theatre, were undergoing thoracic surgery, head or neck surgery including maxillo-facial procedures, had known anatomical laryngo-tracheal abnormalities, had nasogastric tubes in situ or were coughing. Patients receiving nitrous oxide or who refused consent were also excluded.

The anaesthetic technique and the anaesthetic agents used were at the discretion of the anaesthetist in charge of that patient. Inflation of the ETT cuff was done according to the method preferred by the intubating anaesthetist. No ETT cuff pressure was measured within the first 10 min after intubation. The ETT cuff pressure was measured using a RUSCH Endotest™ (Teleflex, South Africa) manometer. The manometer was attached directly to the pilot balloon as showed in Figure 1 and the pressure was recorded at end-expiration. If the ETT cuff pressure was found to be above 30 cm H₂O the pressure was adjusted to fall within the recommended range with the permission of the anaesthetist in charge of the patient. ETT cuff pressures that were below 20 cm H₂O were communicated to the patient's anaesthetist.

The time from intubation to ETT cuff pressure measurement was documented (in minutes) along with the age of the patient (in years), the sex of the patient, and the surgical specialty. The anaesthetist responsible for inflating the ETT cuff was asked what technique was used for cuff inflation and this was then documented together with the ETT cuff pressure obtained with the manometer (in cm H₂O). Anaesthetists were blinded to the study in that they did not know on what days the researcher was collecting data or if they would be included.

Data were captured onto an Excel 2010 (Microsoft®, USA) spreadsheet. STATISTICA 12 (Statsoft, USA) was used to perform the statistical analysis of the data. Normally distributed data were reported using means and standard deviations (SD). Data not normally distributed were reported using medians, ranges and interquartile ranges (IQR). Chi-square and Fisher's exact tests were used to find associations between categorical variables. The Mann-Whitney test was used to compare the ETT cuff pressures between the two hospitals. A *p*-value of < 0.05 is considered to be statistically significant.

Results

There were 96 ETT cuff pressures measured, 48 (50%) from each hospital. The patients taking part in this study included 39 males (40.63%) and 57 females (59.36%). The mean age of the patients was 46 (15) years. The number of patients per specialty is shown in Figure 2.

Anaesthetists took part in this study only once in 71 (73.96%) cases and in 25 (26%) cases anaesthetists were included more than once. Of the latter only two anaesthetists participated in this study three times and both the ETT cuff pressures recorded were still high (> 30 cm H₂O) on the third occasion. The median time from intubation to measurement of the ETT cuff pressure was 45 (30–90) minutes.

The median ETT cuff pressure recorded was 36 cm H₂O (range 10–120 cm H₂O). The RUSCH Endotest™ manometer could only record up to a maximum of 120 cm H₂O, therefore pressures higher than 120 cm H₂O (*n* = 4) were recorded as 120 cm H₂O. The



Figure 1: ETT cuff pressure measurement technique.

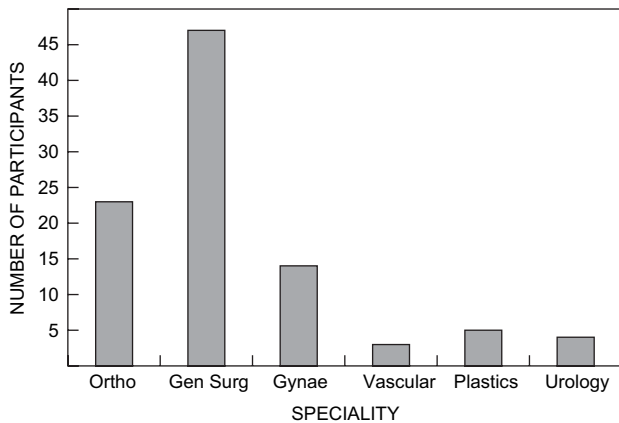


Figure 2: Number of patients per speciality.

ETT cuff pressures were found to be high (> 30 cm H₂O) in 62 (64.58%) patients, with a median pressure of 49 (38–85.5) cm H₂O in this group. ETT cuff pressures of > 100 cm H₂O were recorded in 12 (12.5%) patients. Only 18 (18.75%) patients had a cuff pressure ranging between 20 and 30 cm H₂O, where the median pressure was 28 (26–30) cm H₂O. The remaining 16 patients (16.67%) had ETT cuff pressures lower than 20 cm H₂O, with a median pressure of 16 (14–16.5) cm H₂O.

MOV was the most frequent technique used by anaesthetists to inflate the ETT cuff in 36 (37.5%) patients. Using the PVA technique to inflate the cuff was utilised in 30 patients (31.25%) and palpation of the pilot balloon as an estimate of ETT cuff pressure was used in 26 (27.08%) patients. The remaining

Table 1 shows the different ETT sizes and pressures obtained in each size. Comparison of these was not statistically significant ($p = 0.36$).

At CMJAH the median ETT cuff pressure was 33 (25.5–56.5) cm H₂O, with 26 (54.17%) ETT cuff pressures > 30 cm H₂O. At CHBAH 36 (75%) ETT cuff pressures were > 30 cm H₂O and the median pressure was 40 (31.5–57) cm H₂O. There was no statistically significant difference ($p = 0.07$) between the ETT pressures measured at each hospital. The median pressures and IQR are shown in Figure 3.

Discussion

ETTs are used daily by anaesthetists in the operating theatres of CMJAH and CHBAH without any objective means available to measure the ETT cuff pressures in almost all cases. Only 18 (18.75%) ETT cuff pressures measured at these hospitals were within the recommended range (20–30 cm H₂O). In a study conducted in the United States of America the mean ETT cuff pressure of patients during anaesthesia was 35.3 cm H₂O.⁵ This is above the recommended range, although lower than the results of our study, where the mean cuff pressure was 47.5 cm H₂O. Mean ETT cuff pressure of 27.07 cm H₂O was recorded in a study conducted in a government teaching hospital in India.⁶ Bernon et al.⁷ in 2013, in an academic hospital in Cape Town, reported a mean cuff pressure of 25 cm H₂O in anaesthetised patients. A study conducted in Denmark showed a median ETT cuff pressure of 30 cm H₂O (range 8–100) compared with the median pressure of 36 cm H₂O (range 10–120) recorded in our study.⁸

In our study 62 (64.58%) patients had ETT cuff pressures > 30 cm H₂O, compared with 50% in the American study,⁵ 45% of patients

Table 1: ETT size and ETT pressure groups

Size	Pressure < 20 cm H ₂ O	Pressure 20-30 cm H ₂ O	Pressure > 30 cm H ₂ O	Total	<i>p</i> -value
7.0 ETT	3 (11.11%)	5 (18.52%)	19 (70.37%)	27 (28.13%)	
7.5 ETT	8 (15.09%)	9 (16.98%)	36 (67.92%)	53 (55.21%)	
8.0 & 8.5 ETT	5 (31.25%)	4 (25%)	7 (43.75%)	16 (16.67%)	0.36

techniques used included MLT used in one patient, a manometer owned by the intubating anaesthetist was used in another and a combination of techniques used in the remaining two patients. There was no statistically significant difference ($p = 0.13$) between the different inflation techniques and the cuff pressures obtained.

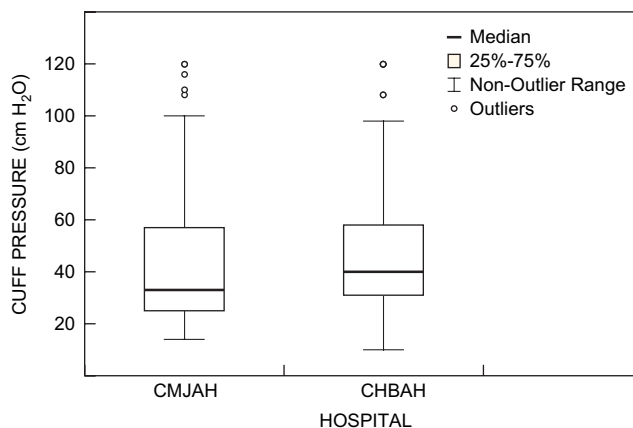


Figure 3: Box and whisker plot of pressures at each hospital.

in the Danish study,⁸ 26.2% in the Indian study⁶ and 23% in the Cape Town study.⁷ Only 18 (18.75%) patients in our study had an ETT cuff pressure within the normal range whereas in the American study 27% of patients had normal ETT cuff pressures and in the Indian study 59% of ETT cuff pressures were normal. ETT cuff pressures < 30 cm H₂O were reported in 77% of patients in the Cape Town study.^{5–8} It is important to note that in our study data were collected at times convenient for the researcher over an extended period of time. This may reflect the normal practice of the anaesthetist more accurately than the Denmark and Cape Town studies where mean ETT cuff pressures lower than ours were reported. The anaesthetists in these two studies were aware that a study was being conducted whereas in our study the researcher arrived unannounced on random days at each hospital to record the ETT cuff pressures.^{7,8} Also, a maximum of three ETT cuff pressure measurements from any one anaesthetist was included in our study. None of the discussed studies^{5–8} specified the maximum number of ETT cuff pressure measurements that was allowed in the study as recorded by any single anaesthetist.

The two most common inflation techniques used in our study were MOV (37.5%) and PVA (31.25%). This was followed by the palpation of the pilot balloon technique in 27.08% and other

inflation techniques in 4.17% of cases. No statistically significant difference was found between the inflation technique and the ETT pressures obtained. This has been documented in other studies where the reliability of cuff pressure estimation techniques was deemed to be very low.^{5-7,9} Previously mentioned studies^{5,7} have compared the ETT size with the ETT cuff pressure and have found that there was no statistically significant difference between the two parameters. This was also evident in our study.

There was a difference of 7 cm H₂O between the median ETT cuff pressures recorded at each hospital. Although not statistically significant this difference is an interesting observation, particularly when it is taken into consideration that the same registrars rotate through the two hospitals. One possible explanation could be that junior medical officers and interns, who do not rotate, inflated the ETT cuffs at CHBAH and contributed to this, although it has been shown that the experience of the person inflating the ETT cuff does not influence the pressure obtained.^{5,7,9-11}

Limitations

The designation and experience of the intubating anaesthetist was not documented, to ensure confidentiality. Interns and medical officers are often responsible for intubation and inflation of the ETT cuffs, as they need to obtain experience in a limited period of time. The results, therefore, may not accurately reflect the ETT cuff management practice of the entire anaesthetic staff affiliated to these two hospitals.

The ETT brand was not documented when the ETT cuff pressure was measured. This limits the interpretation of results, as lesser known brands of ETTs are used in the theatres of the two hospitals. This may have resulted in higher ETT cuff pressures, as the researcher could not find guidelines on the standards to which South African ETTs must conform.

Conclusion

The results of this study indicate that ETT cuff pressures of patients undergoing general anaesthesia at CMJAH and CHBAH are not ideal. At both hospitals it was found that ETT cuff pressure is higher than the recommended range of 20–30 cm H₂O. There is

a need for an objective means of measuring ETT cuff pressure, and it is therefore prudent that manometers become available in the operating theatres of these hospitals.

Conflict of interests – The authors declare no conflict of interest.

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