South Afr J Anaesth Analg. 2025;31(4):121-125
https://doi.org/10.36303/SAJAA.3237

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

ORIGINAL RESEARCH

Management of endotracheal tube cuff pressures in the intensive care unit at a tertiary hospital: a review of the adequacy of current practices

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Background: The inappropriate management of endotracheal tube (ETT) cuff pressures in ventilated patients in the intensive care unit (ICU) is associated with myriad complications and increased morbidity and mortality.[1,2] International recommendations agree that ETT cuff pressure should be maintained in the 20–30 cmH_2O range to minimise potential harm to intubated patients.[3-8] Currently, the ICU at Dr George Mukhari Academic Hospital (DGMAH) has no formal protocol for ETT cuff pressure management, potentially exposing patients to risk and the hospital to increased healthcare costs and burdens. This study investigated whether ETT cuff pressure management practices in the ICU at DGMAH aligned with the recommended standard and allowed pressures to remain within the 20–30 cmH_2O range.

Methods: Over three months, 205 patients, within 24 hours of admission to the ICU, were recruited in a prospective, observational cross-sectional survey. The initial ETT cuff pressure was measured. If the pressure was outside the 20–30 cmH_2O range, the volume of adjustment needed to bring the measurement into range was documented. The minimal pressure at which a leak was occluded clinically by auscultation was recorded.

Results: In our study, 25% of patients (95% confidence interval [CI] 19.9% to 31.7%) surveyed had ETT cuff pressures within the recommended range, with 65% (95% CI 57.6% to 70.6%) falling over the upper threshold, and 21% (95% CI 6.8% to 15.2%) being underinflated according to the recommendations. Of the 205 participants, 153 (74.6%) required adjustment of their ETT cuff pressure at the time of data collection, with 121 (59%) achieving a clinical seal below the reference range.

Conclusion: We concluded that the current practice of measuring the ETT cuff pressure at the discretion of the treating clinician without a standardised protocol results in a significant percentage of patients with inappropriate cuff pressures going undetected.

Keywords: adults, endotracheal tube cuff pressures, cuff manometer, intensive care unit, controlled ventilation

Introduction

Inappropriate management of ETT cuff pressures in ventilated patients in the ICU is associated with various complications, leading to increased morbidity and mortality and prolonged ICU and hospital stay.[1,2] Cuffed ETTs have been used to facilitate mechanical ventilation in critically ill patients for over 130 years.[2] First described by Eisenmenger in 1893, the purpose of the cuff was to ensure the adequacy of invasive ventilation and to provide a physical barrier to fluid or particulate matter and pathogenic microorganisms originating in the gastrointestinal tract.[9]

While advances in medical technology have led to significant improvements in the design and materials of modern ETTs, risks and complications continue to plague patients undergoing this potentially life-saving intervention. A persistent problem, ubiquitous in the discourse in the field of critical care, is the inappropriate over- or underinflation of endotracheal cuffs. After the acute insult, this damage may heal with fibrosis, resulting in stenotic lesions of the subglottic area in up to 20% of patients, in addition to injuring adjacent structures, such as the nerves and vocal folds.[5,6,8,10-12]

International guidelines recommend maintaining ETT cuff pressures within a range of 20–30 cmH_2O to minimise potential harm to intubated patients, while local protocols advocate for a narrower range of 25–30 mmHg.[1,3,4,7,9,10,12-18] The higher lower limit in local recommendations reflects concerns about the risk of microaspiration at cuff pressures below 25 mmHg.[18] Emerging research has prompted many international and South African authors to recommend adopting continuous electronic monitoring systems for mechanically ventilated patients in the ICU setting if possible.[1,17,19]

In the resource-constrained setting, most guidelines advise that intermittent cuff pressure measurements be carried out using a cuff manometer designed for this purpose. However, the literature has considerable heterogeneity regarding how frequently this should be performed. Many international authors suggest at least once every eight hours.[1,20-22] The South African standard is 12-hourly measurements; however, some authors suggest that more frequent intervals may enhance patient safety.[17-19,23]

Several factors can influence ETT cuff pressure, including patient position, neck position, coughing, airway interventions such as respiratory toilette, and the level of sedation.[23,24] Additionally, cuff pressure tends to decrease over time due to changes in the compliance of the cuff material, with significant reductions observed as early as four hours post-intubation.[1,21] Given these dynamic influences, cuff pressure may deviate from the optimal range despite being appropriately set at the time of intubation.

Frequent monitoring and adjustments are essential to maintain safe and effective cuff pressures throughout intubation.

ICU practitioners often rely on subjective, inaccurate techniques to estimate the internal cuff pressure. While manual manometry using a hand-pressure gauge is a simple and feasible method, continuous electronic monitoring with automated alarm systems is increasingly regarded as the gold standard for ensuring safe and consistent cuff pressure management.[1,17,19]

The ICU at DGMAH, a large tertiary hospital with a 22-bed multidisciplinary ICU, currently has no formal protocol for ETT cuff pressure management, potentially exposing patients to risk and increasing the burden on limited healthcare resources. This study aimed to investigate whether patients being ventilated at DGMAH are exposed to over- or underinflation of ETT cuffs in daily practice.

Methods

This observational cross-sectional study was approved by the Sefako Makgatho Health Sciences University Research Ethics Committee (SMUREC/M/02/2023). Gatekeeper consent was obtained from the hospital's superintendent and the head of the ICU, which was accepted by SMUREC instead of individual patient consent, as the measurement of cuff pressure is part of the intubated patient's routine care. The study was performed from April to July 2024 in the ICU at DGMAH, a tertiary healthcare facility in the Tshwane Municipality of Gauteng that provides intensive care to medical and surgical patients. The study aimed to determine the percentage of intubated patients with ETT cuff pressures within the target range and those with over- or underinflated cuffs.

Participants were recruited within 24 hours of admission to the ICU and were not re-entered if reintubation occurred. Inclusion criteria were patients aged 18–80 years who were orally intubated with a cuffed ETT, undergoing conventional invasive ventilation*, and nursed supine or in a 30-degree head-up position with the neck in a neutral position. Patients were excluded if they had any cervical spine or upper airway pathology, were ventilated through a tracheostomy, were agitated or experiencing patient-ventilator dyssynchrony (as identified by the principal investigator), or if the Richmond Agitation-Sedation Scale (RASS) score was higher than +1.[25]

All data were collected by the primary researcher and de-identified to ensure patient confidentiality. Demographic data and the time of intubation were collected from medical records. If a patient's weight was not recorded, anthropometric measurements were taken by the principal investigator using a standard measuring tape with 1 cm increments to estimate the weight by a mid-arm, circumference-based equation validated for use in adult patients.[26] The depth to which the ETT was inserted was read from the markings printed on the tube in 1 cm increments, with the recorded depth documented as the marker closest to the upper central incisors. Ventilator parameters were recorded at the time of measurement before connecting the cuff manometer.

A universal cuff manometer (VBM Medizintechnik, Sulz am Neckar, Germany) was attached to the ETT pilot balloon via a three-way stopcock and used to measure and document the initial internal cuff pressure at the end of the inspiratory phase of ventilation by the same observer in all cases. This measurement was used to determine whether the cuff pressure fell within the recommended range. If the initial cuff pressure fell outside this range, the air was aspirated or inflated in 0.5 ml increments using a micro syringe to reach that pressure. The total volume aspirated or inflated to reach the target range in increments was tallied and recorded.

The cuff was then deflated in 0.5 ml increments to determine the pressure at which a leak is clinically detected and occluded by auscultation over the trachea using a stethoscope and observing ventilator parameters for loss of tidal volume. This revealed participants in which the pressure required to occlude the airway fell below the minimal 20 cmH_2O threshold. The cuff was then reinflated if necessary to reach the target range before data collection was completed.

Statistical analysis

Non-probability consecutive convenience sampling was used. The required sample size was determined in consultation with a biostatistician to be 201, assuming 25% of patients would have cuff pressures within the normal range. The expected frequency of the cuff pressure being in range was based on data from three local and three international studies, showing 17–28% of pressures being in range.[6,15,18,19,27,28] This ensures that the two-sided 95% CI for the proportion of cases with cuff pressures in the target range would have a margin of error of ± 6%.

Demographic and clinical characteristics are summarised descriptively. Continuous data were inspected for normality (Shapiro–Wilk test) and summarised with median and 25th–75th centiles (Q1, Q3). Categorical data are summarised by frequency counts and percentage calculations.

The percentage of patients whose endotracheal cuff pressure fell within, below, or above the target range was calculated together with a 95% CI. Median values were calculated for the volume of air required to adjust the measured pressure to a target range of 20–30 cmH_2O. The percentage of patients who required pressures lower than the recommended minimum of 20 cmH_2O was calculated. Where appropriate, comparisons were made with the Wilcoxon rank-sum test, and median differences were assessed with the Hodges–Lehmann estimate.

Data were collected in a spreadsheet on Microsoft® Excel® for Microsoft 365 MSO (version 2408, Build 16.0.17928.20114) 64-bit, running under Microsoft Windows on a personal computer. The

* Referring to ventilation with any of the following modes: SIMV[VC]+PS, PSV/CPAP, SIMV-VCV, SIMV-PCV, A/C-VCV

statistical analyses were performed in Stata (StataCorp, College Station, United States).

Results

A total of 205 consecutive patients were recruited. Demographic and ventilatory data are summarised in Table I. Intubation duration was divided into four-hour intervals, and the frequency of measurements during each period was determined. All data were collected within 24 hours of admission to the ICU and a median of 13.5 hours after intubation.

The initial internal ETT cuff pressures were recorded and grouped according to their relation to the recommended reference range (Table II). Of the patients, 52 (25%) had initial cuff pressures within the recommended range, and 132 patients (65%) had to have their cuffs deflated due to over-pressurisation. The median (Q1, Q3) volume adjustment required through inflation or deflation of the cuff was 0.7 ml (0.0, 1.7). Clinical leak occlusion occurred below the recommended reference range in 121 patients (59%). The leak occlusion pressure could not be determined in 36 patients (17.6%).

Using the Wilcoxon rank-sum test, the median cuff pressure of the first 60 patients was compared to that of the last 60 patients to assess whether cuff pressure management improved during the duration of the study, with no significant difference detected (median difference 4, 95% CI -12 to 2; $p = 0.213$).

There were 30 patients with RASS scores of +1 (restless). The median cuff pressure of this subgroup was 40 cmH_2O (26, 56), with 20 (66%) of these patients having a cuff pressure outside the target range. Compared to patients with the deepest level of sedation (RASS -5), only 4/57 patients in this subgroup had cuff pressures in the target range, with 93% of patients falling outside the desired range. There was no significant difference between the median scores of the patients with RASS scores of +1 or -5 to 0 (median difference 0, CI -8 to 8; $p = 0.996$).

The relationship between the adjusted volume and pressure was investigated by sorting the pressures into categories and calculating the median pressure and median adjusted volume for each category (Table III).

Discussion

This study demonstrates that most intubated patients in the ICU at DGMAH were exposed to over- or underinflated ETT cuffs. The most concerning finding from this study is that 65% of patients had overinflated cuffs, with almost half (49%)

Table I: Demographic and ventilatory data

	All patients *n* = 205
Age, years	47 (33, 58)
Sex, female/male	80 (39)/125 (61)
Weight, kg	73 (62, 86)
Height, cm	169 (162, 178)
BMI	25.8 (21.6, 29.4)
Depth of tube insertion, cm	23 (22, 24)
Duration of ventilation at the time of assessment, hours	13.5 (6.8, 18.5)
0–4	18 (9)
> 4–8	42 (21)
> 8–12	29 (14)
> 12–16	45 (22)
> 16–20	38 (18)
> 20–24	33 (16)
Ventilator parameters	
Tidal volume, ml/kg	6.1 (5.2, 7.3)
Respiratory rate, per minute	16 (14, 19)
PEEP, cmH_2O	6 (5, 8)
Ventilation mode	
SIMV(VC)+PS	122 (59.5)
PSV/CPAP	46 (22.5)
SIMV-VCV	31 (15.1)
SIMV-PCV	5 (2.4)
A/C-VCV	1 (0.5)
RASS score at the time of assessment	
Unarousable (-5)	57 (28)
Deep sedation (-4)	32 (15)
Moderate sedation (-3)	12 (6)
Light sedation (-2)	12 (6)
Drowsy (-1)	20 (10)
Alert and calm (0)	42 (20)
Restless (+1)	30 (15)

All data are shown as frequency (%) or median (Q1, Q3).
A/C-VCV – assist-control ventilation with volume-controlled ventilation, BMI – body mass index, PEEP – positive end-expiratory pressure, PSV/CPAP – pressure support ventilation and continuous positive airway pressure, RASS – Richmond Agitation-Sedation Scale, SIMV(VC)+PS – synchronised intermittent mandatory ventilation with volume control and pressure support, SIMV-PCV – synchronised intermittent mandatory ventilation with pressure control ventilation, SIMV-VCV – synchronised intermittent mandatory ventilation with volume control ventilation

Table II: Initial internal cuff pressure

	Frequency		Cuff pressure (cmH_2O)	
	n (%)	95% CI	Median (Q1, Q3)	95% CI of median
Cuff pressure below RR	21 (10)	6.8 to 15.2	16 (14, 18)	14 to 18
Cuff pressure within RR	52 (25)	19.9 to 31.7	25 (22, 28)	24 to 26
Cuff pressure above RR	132 (65)	57.6 to 70.6	52 (42, 65)	49 to 55

CI – confidence interval, RR – reference range (20–30 cmH_2O)

Table III: Pressure categories and volume adjusted per pressure category

Pressure category	Number of observations	Median pressure (cmH_2O) (Q1, Q3)	Median volume adjusted (ml) (Q1, Q3)
0 – < 10	3	8 (8, 8.5)	+1.4 (0.9, 1.8)
10 – < 20	18	18 (16, 18)	+0.3 (0.1, 0.5)
20 – 30	52	26 (24, 28)	0.0 (0, 0)
> 30 – 40	32	38 (35, 40)	-0.5 (-0.3, -0.6)
> 40 – 50	32	46 (42, 48)	-1.0 (-0.7, -1.2)
> 50 – 60	27	56 (54, 58)	-1.5 (-1, -2)
> 60 – 70	18	66 (64, 66)	-2 (-2, -2.5)
> 70 – 80	5	74 (74, 76)	-2.5 (-2.5, -2.5)
> 80 – 90	12	86 (83, 89)	-2.5 (-2, -3)
> 90 – 100	1	92 (92, 92)	-3.2 (-3.2, -3.2)
> 100	5	110 (106, 116)	-3.5 (-3.5, -4)

+ Indicates that the cuff was inflated.
- Indicates that the cuff was deflated.

exhibiting pressures exceeding 40 cmH_2O. This is particularly significant given that the estimated perfusion pressure of the submucosal vessels in the tracheal wall ranges between 30 and 41 cmH_2O.[6] Inflating the ETT cuff beyond this threshold may lead to ischaemia of the tracheal mucosa and deeper structures, initially presenting as inflammation and fibrin deposition, which can progress to ulceration, erosion, and even tracheal rupture in severe cases.[5,6,12,29] Pressure-induced damage to the tracheal cilia and mucosa occurs rapidly, with involvement of the basement membrane after just two hours of cuff pressures exceeding 25 cmH_2O.[11]

An air leak around the ETT cuff or cuff pressure < 20 mmHg increases the risk of aspiration of oropharyngeal and gastric secretions and debris, predisposing patients to ventilator-associated pneumonia (VAP), with a mortality rate of nearly 80%.[1,4,10,12,30] In this study, 12% of patients (*n* = 25) had underinflated cuffs, placing them at potential risk for this serious complication.

International studies recommend maintaining ETT cuff pressures between 20 and 30 cmH_2O to prevent complications

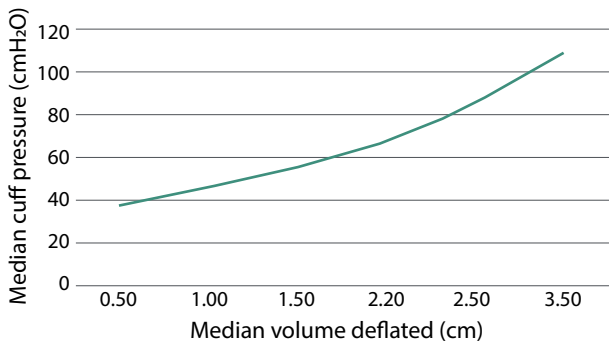

Figure 1: Pressure versus volume adjustment, the relationship between the initial ETT cuff pressure of those observations that exceeded 30 cmH_2O, and the volume of air removed to bring the pressure into the recommended range

of over- or underinflation.[1,3,4,7,9,12-16] In a 2019 editorial on cuff pressure management, Gopalan refers to a South African guideline recommending a narrower target of 25–30 cmH_2O, with many other local investigators using < 30 cmH_2O as their threshold.[5,17,28,29] The findings from this study are consistent with other local reports, where the proportion of ETT cuffs maintained within the recommended range has been equally low. Khan et al.[18] reported 17% of ETT cuffs within the normal range, Gilliland et al.[6] found 18.75%, and Hardcastle et al.[19] reported cuff pressures in range in 23% of patients. International studies have similar results, with only 27–28% of cuff pressures being in range.[15,27,28] This underscores the message that protocols for ETT cuff pressure assessments and adjustment are vital to prevent adverse outcomes in critical care patients.

As illustrated in Figure 1, our findings indicate that internal cuff pressure and the required volume adjustment follow a linear trend. This pattern was observed in previous human and animal studies.[21,31] These results highlight the sensitivity of cuff pressure to small variations in inflation volume, with a median excess inflation volume of just 3.5 ml generating cuff pressures exceeding 100 cmH_2O.

Reasons for poor guideline adherence are explored in a few studies. Factors that have been identified include:[12,18]

- complacency regarding the risks of inappropriate cuff pressures,
- the unavailability of necessary equipment,
- concern over the pressure loss often caused by intermittent measurement devices, and
- a lack of role-modelling of correct practice by supervisors.

The debate continues on the frequency of recommended ETT cuff pressure measurement in the literature, with more conservative recommendations indicating that three times per day (every eight hours) should be the required minimum.[12] Most patients in our sample were assessed after the eight-hour mark. Considering that only a quarter of cuff pressures were within the recommended range at the time, this implies that most patients had not had their cuff pressures checked and adjusted within the preceding eight hours, exposing them to prolonged periods of excessive or insufficient cuff pressure. Our findings echo those of Memela et al.,[23] who studied both continuous and intermittent (eight-hourly) ETT cuff measurements in 35 critically ill patients at a tertiary hospital in South Africa in 2014 over 12 hours. Their study revealed frequent pressure fluctuations outside the recommended range, leading them to recommend increasing the frequency of cuff pressure assessments beyond eight-hourly intervals.[23]

The ICU at DGMAH uses the SERVO-air ventilator system by the Maquet Getinge Group. Most patients enrolled in the study were ventilated using the SIMV(VC)+PS mode, with mandatory controlled breaths delivered to the patient at a preset respiratory rate and inspiratory pressure while allowing spontaneous pressure-supported breaths.[32] Air leaks were abolished in 121 patients (59%) at pressures below the recommended range.

We relied on clinical leak detection by auscultation rather than spirometry, which can detect minute circuit leaks and requires an additional 4 cmH_2O of pressure to completely seal the airway.[24] In many cases, it was difficult to detect by auscultation alone when a leak became clinically apparent, and in some, it was impossible due to patients developing coughing episodes from tracheal irritation. Therefore, these variables potentially led to measurement inaccuracies and should be addressed in a more controlled setting with a revised methodology.

Study limitations and recommendations

There are several limitations to this study. Only a single cuff pressure reading was obtained per participant, preventing the ability to analyse variations over time. Additionally, certain factors known to affect cuff pressure, such as patient positioning, neck flexion, and the act of connecting the manometer to the pilot balloon, could not be fully controlled.[3,4] While performing measurements in the ICU, the principal investigator often explained the purpose of the study to nursing staff and anyone who showed interest, potentially introducing bias by inadvertently educating personnel responsible for caring for intubated patients that frequent ETT cuff pressure measurement and adjustment is critical. However, an analysis of the temporal distribution of readings showed no significant improvement in cuff pressure management over time, suggesting that this effect was minimal. Additionally, this study was not designed for long-term follow-up, meaning that patients exposed to high cuff pressures were not monitored for the development of tracheal injury or other complications. Finally, as a single-centre study, the findings may not be generalisable to other settings; however, the consistency with local and international studies suggests that these issues are widespread.

The study's results may interest healthcare policymakers and hospital administrators seeking to develop standardised patient care policies and protocols. This study did not explore the underlying reasons for poor adherence to cuff pressure monitoring guidelines. Potential contributing factors include a lack of awareness, insufficient training, inadequate access to equipment, and human error. Identifying and addressing these challenges should be a priority for future research, particularly in the context of quality improvement initiatives to optimise cuff pressure management in ICU settings.

Conclusion

This study showed that current endotracheal cuff pressure management practices in the ICU at a tertiary hospital in South Africa are inadequate. This may lead to negative patient outcomes and increased healthcare resource requirements. Further research into barriers to adherence, along with cost-effective strategies for improving monitoring practices, is essential to enhance cuff pressure management and improve patient safety in critical care settings.

Acknowledgements

The authors acknowledge the staff at the intensive care unit at Dr George Mukhari Academic Hospital for their patience and assistance during the many visits for data collection.

Conflict of interest

The authors declare no conflict of interest.

Funding source

No funding source to be declared.

Ethical approval

This observational cross-sectional study was approved by the Sefako Makgatho Health Sciences University Research Ethics Committee (SMUREC/M/02/2023).

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