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ORIGINAL RESEARCH ARTICLES

Endotracheal tube cuff pressures and tube position in critically injured patients on arrival at a referral centre: Avoidable harm?[☆]



Pression du brassard de sonde endotrachéale et position de la sonde chez les patients gravement blessés à l'arrivée dans un centre d'orientation: un mal évitable?

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Introduction: The consequences of excessive endotracheal tube (ETT) cuff pressure are known and have long-term effects; however less attention is placed upon cuff pressure and tube position pre-hospital and in emergency centre. The aim of this study was to evaluate the ETT cuff pressure and tube position on arrival of all patients admitted to the Trauma Unit at Inkosi Albert Luthuli Central Hospital, both from scene and inter-hospital transfers to determine the median cuff-pressure and if there were differences between the two groups.

Methods: Data from Trauma Unit patients are entered into a prospective; UKZN approved (BE207-09) Trauma Database. Data on 65 admissions between April and December 2014 were reviewed to determine the arrival cuff pressure and tube position. Data captured included patient age, cuff pressure, where and who intubated the patient, and time since intubation to cuff pressure check. Data were analysed by descriptive statistics and Student's *t*-test for continuous data.

Results: Most patients had sustained motor vehicle related trauma, with a male predominance. Equal numbers were intubated pre-hospital versus the in-hospital group. Eighty percent of ETT's were placed in the correct anatomical location, however only 23% of cuff pressures were found to be within the safe pressure limits. ETT cuff pressures were excessive in the pre-hospital ALS group more often than the facility-intubation group ($p = 0.042$). There were fatal complications related to supra-glottic intubations resulting in aspiration pneumonia, highlighting the need for X-ray confirmation of tube position.

Conclusion: Most patients, whether intubated on-scene or at hospital have ETT cuff pressures that are excessive, with the potential for ischaemic necrosis of the tracheal mucosa. ETT cuff manometry should be standard of care for all prehospital and in-hospital intubations where the tube will remain in situ for any prolonged period of time. Before inter-facility transfer ETT position should be confirmed radiologically.

Introduction: Les conséquences d'une pression excessive du brassard de sonde endotrachéale (ETT) sont connues et ont des effets à long terme; mais une moindre attention est accordée à la pression du brassard et à la position de la sonde avant l'hospitalisation et au service d'urgence. Le but de cette étude était d'évaluer la pression du brassard de l'ETT et la position de la sonde à l'arrivée de tous les patients admis au Service de traumatologie de l'Hôpital central Inkosi Albert Luthuli, amenés directement du lieu de l'accident ou venant des transferts entre hôpitaux, afin de déterminer la pression de brassard médiane et s'il existe des différences entre les deux groupes de patients.

Méthodes: Les données tirées des patients du Service de traumatologie sont saisies dans une base de données de traumatologie prospective validée par l'UKZN (BE207-09). Les données de 65 admissions entre avril et décembre 2014 ont été examinées afin de déterminer la pression du brassard et la position de la sonde à l'arrivée. Les données saisies incluaient l'âge du patient, la pression du brassard, qui avait intubé le patient et où, et le temps écoulé entre l'intubation et le contrôle de la pression du brassard. Les données ont été analysées selon des statistiques descriptives et le test *t* de Student sur les données continues.

Résultats: La plupart des patients avaient subi des traumatismes liés à des véhicules motorisés, avec une prédominance masculine. Un nombre équivalent avaient été intubés avant l'hospitalisation par rapport au groupe intubé à l'hôpital. Quatre-vingt pour cent des ETT avaient été positionnés dans la bonne position anatomique, mais il a été constaté que seulement 23% des pressions de brassard se situaient dans la fourchette de sécurité des limites de pression. Les pressions de brassard d'ETT étaient plus souvent excessives au sein du groupe en réanimation d'urgence intubé en pré-hospitalisation que celles du groupe intubé au centre ($p = 0.042$). Des complications mortelles liées à des intubations supraglottiques résultant en une pneumonie par aspiration ont été constatées, ce qui souligne la nécessité d'une confirmation par radiographie de la position de la sonde.

Conclusion: La plupart des patients intubés, qu'ils l'aient été sur place ou à l'hôpital, présentent une pression de brassard d'ETT qui est excessive, avec un potentiel de nécrose ischémique de la muqueuse trachéale. La manométrie du brassard de l'ETT doit être la norme de soins pour tous les soins pré hospitaliers et à l'hôpital lors des intubations prévoyant que la sonde restera en place pendant une longue période. Avant un transfert entre établissements, la position de l'ETT doit être confirmée radiologiquement.

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African relevance

- Paramedics and medical doctors are poor at checking cuff pressure, with a higher risk for paramedics.
- Optimal cuff pressure is 1 cm H₂O above peak pressure.
- Optimal tube placement should be 2–3 cm above the carina and checked with X-ray.

Introduction

Emergency airway management is an essential skill for prehospital providers, emergency medicine, family medicine and trauma surgery practitioners.^{1,2} The focus has moved from simply “getting the tube in” to ensuring adequate oxygenation and exchange of carbon dioxide. For this reason alternative airway devices and nasal probe oxygen during intubation have become popular.^{3,4} Despite this, definitive airway devices (endotracheal tubes [ETT] and tracheostomy tubes), remain the conduit of choice for airway protection and ventilation in patients with major trauma.

Trauma remains a malignant epidemic.⁸ KwaZulu-Natal has an immature trauma system, with most patients admitted first to district or regional hospitals and facing multiple transfers until they reach definitive care. A proportion may be admitted directly to regional and tertiary/quaternary centres from the scene of the trauma, with many of these patients undergoing on-scene intubation by paramedical staff.^{5–7}

ETT placement confirmation and correct positioning are essential, with the tip ideally placed mid-trachea, about 2–3 cm above the carina.⁹ This avoids subglottic slip and accidental extubation into the supraglottic space, with subsequent air-leak and aspiration risk, and also avoids right main-stem bronchial intubation.

An undervalued aspect of airway management in emergencies however, has been the pressure generated in ETT cuffs after instillation of air (or saline in aeromedical cases) to provide the cuff-seal. Internationally the trend has been towards regular measurement of cuff pressures with a manometer, although the routine adoption of this practice has been variable.¹⁰ The accepted norm is to maintain a cuff pressure between 20 and 30 cm H₂O to avoid tracheal mucosal ischaemia, or for those on higher pressure ventilation, to maintain a pressure at least 1 cm H₂O above the peak pressure ventilator setting to avoid an unnecessary leak of air.^{10,11}

The aim of this study was to measure the ETT cuff pressure and ETT position on arrival at the IALCH Trauma Unit and to compare the direct-from-scene group to those referred from other hospitals, in terms of the absolute pressure and duration of ETT placement.

Methods

The study was performed at the quaternary referral trauma service of the Inkosi Albert Luthuli Central Hospital, a facility meeting the requirements for a Level 1 Trauma Centre of the Trauma Society of SA¹² and included consecutive patients admitted to the service between April and December of 2014 for whom there was a documented cuff-pressure reading

and/or position check of the ETT, recorded on arrival at the Trauma Receiving Unit. The ETT cuff pressures were measured on handover using a VBM cuff-manometer (VBM Medizintechnik, Sulz, Germany), with a pressure range from 0 to 120 cm H₂O. The demographics (age, sex), mechanism of injury, ETT size, position of the tip in the trachea and the skill level of the intubator were retrieved from the UKZN-BREC Class-approved Soarian® (Siemens, Germany) Database (Ethics approval BE207-09) and analysed using descriptive statistics, Student's *t*-test for continuous data, and Chi-squared for categorical data with GraphPad (GraphPad Software Inc, La Jolla, CA).

Results

Of 65 resuscitation room cases of a total of 191 consecutive trauma unit admissions cuff pressures were documented in 61 (32%). In 4 patients the pressure was not recorded (3 from regional hospitals with the tube position noted to be clinically incorrect, including one in the oesophagus, and one from scene (with CPR in progress), where tube position was immediately adjusted on arrival, precluding a pressure check. These 4 were excluded from further evaluation of cuff pressure but are included in assessment of ETT position. Other exclusions were those where the cuff pressure was not documented, children with non-cuffed tubes, those who were not intubated prior to arrival at the unit, and those admitted to the ICU directly from theatre and not via the resuscitation room. [Table 1](#) details the variables reviewed in this study.

Twenty-eight (43%) admissions were directly from the incident scene, while the other 37 (57%) were inter-facility transfers. The source of the inter-facility transfer was a regional hospital in 16, another tertiary hospital in 15, clinic or district hospital in 4, and 2 transfers from the private sector. Location of transfer was from the ward or ICU in 24, emergency centre in 8, and from the operating theatre in 5 cases.

Ages ranged from 3 to 79 years, with a median of 30 years (interquartile [IQR] range of 24–40). There were 51 (78.4%) males in the cohort, in keeping with trauma profiles ($p < 0.001$). The predominant injury mechanism was motor vehicle collision (35 pedestrians, 9 passengers, 7 drivers, and 3 motorcyclists) the other injury mechanisms being 6 blunt assault, 3 gunshot wounds and 1 each caused by stab wound and dog-bites ($p < 0.001$). ETT sizes ranged from 4 to 9 mm internal diameter, with a median of 7.5 mm (IQR 7–7.5). Thirty one (47%) intubations were performed by Advanced Life Support (ALS) paramedic practitioners, 33 (51%) intubations were by various grades of medical officer, while only one (2%) was performed by a registrar level trainee.

Cuff pressures ranged from a low of 10 cm H₂O to in excess of 120 cm H₂O. Comparison of the origin of the patient (scene versus interfacility transfer) showed that the median paramedic cuff-pressure was 70 cm H₂O (IQR 60–120 cm H₂O), while the interfacility transfer group had a median pressure of 60 cm H₂O (IQR 24–90 cm H₂O) ($p < 0.001$) ([Table 2](#)). Twenty three percent of cuff pressures were within the acceptable range and 27% were in excess of systolic blood pressure (> 120 cm H₂O). The remaining 50% were over 30 cm H₂O but less than 100 cm H₂O. When the two groups are compared 27% of the

inter-hospital group had acceptable cuff pressures, while only 11% of the prehospital ETT's had acceptable cuff pressures on admission ($p = 0.04$) indicating a statistically higher proportion of excessive cuff pressures in following intubation by the ALS paramedic. All 11 patients with cuff pressure within the normal range had this checked specifically by the treating surgeon, ICU consultant or paramedic prior to transfer, having had prior education on the importance of this aspect of airway care.

ETT position in the trachea was correct in 51 (80%) patients but was found in the right main bronchus in 5 and abutting the carina in 2 cases. In five patients the ETT was supraglottic and in one subglottic, directly below the vocal cords. One patient presented with the ETT in the oesophagus and a cuff pressure of 120 cm H₂O. This tube was replaced and the cuff pressure set to 30 cm H₂O. This included the oesophageal placement, which was performed by a medical officer at the referring facility and the patient then transferred over 40 km by ambulance without this malposition being recognised by either the sending doctor, or the treating paramedic in transit. Three patients with supra-glottic tubes suffered aspiration pneumonia with one fatality, a potentially preventable demise.

ETT duration prior to admission to IALCH varied from 0.5 to 72 h, with a median of 3 h (IQR 1–7 h). Patients from scene arrived with times ranging from 0.5 to as long as 12 h (median 1 hour, IQR 0.5–2 h). Four prehospital scene calls had prehospital times in excess of 4 h, mainly resulting from prolonged entrapment or rural retrievals/mountain rescues. The interfacility transfers ranged from 1 to 72 h (median 5 h, IQR 3–8 h).

Discussion

Iatrogenic injury and medical misadventure remain a common aspect of emergency care.¹³ ETT malpositions commonly present early, with supraglottic cuff location associated with air-leak, aspiration and subsequent pneumonia, while right mainstem bronchial intubation is associated with left lung collapse, hypoxia, hypercarbia and right lung overinflation with associated baro-trauma, volutrauma, and biotrauma. Atelectrauma may also occur in the left lung. All these impact on the success of mechanical ventilation and the ability to recruit the traumatised lung, especially important in trauma patients with lung contusion or dependent atelectasis.

If the errors are not recognised early they contribute to episodes of patient deterioration and prolonged ICU stay as a result of aspiration pneumonia, ventilator associated pneumonia or lung collapse. Prolonged excessive cuff-pressure may present acutely with a trachea-oesophageal fistula, however the consequences of mucosal ischaemia may only present weeks to months after discharge from the ICU or hospital.¹⁴ The incidence of subsequent tracheal stenosis is uncertain, but is likely to result in re-admission and in some cases the need for tracheal resection or laser therapy to remodel the trachea.

Prevention is better than cure, which makes the findings of this small series all the more concerning, considering that the cuff-pressure was excessive in all but 15 patients in the total cohort, implying that over 75% of patients were at risk of tra-

cheal mucosal ischaemia. In fact, 27% of the cohort had cuff-pressures equating to normal systolic blood pressure, meaning that tracheal ischaemic changes were likely, given that many were hypotensive on arrival.

Post-extubation sore throat, hoarseness and stridor are common complications with endoscopic mucosal denudation common after prolonged intubation with incorrect cuff pressure, both acutely (within 15 min) and on long-term follow-up.^{10,15–18} The complications of low pressures include microaspiration and therefore ideal cuff pressures and 5–8 cm H₂O of PEEP are recommended, along with keeping patients head-up, while the risk of high cuff-pressures for long-duration intubation includes tracheal stenosis and tracheo-oesophageal fistula.^{11,19}

The most comprehensive review of the effect of incorrect cuff pressures was by Sultan et al.¹⁰ where it was highlighted that modern ETT's with high-volume low pressure cuffs have less damaging effects on the tracheal mucosa than the older ETT's and that the most preferred method of cuff inflation is the Minimal Occlusive Volume (MOV) technique, which requires inflation of air into the ETT cuff to prevent any air leakage. It is potentially inferior to the manometer guided method, but better than the minimal leak technique.¹⁰ It was also highlighted that using a specific volume of air for varied size tubes is not reliable.^{10,20–22}

Only 5 of the 13 malpositioned tubes were placed by the paramedic practitioner, implying that medical practitioners also do not follow standard practice and check tube-tip position with a chest X-ray, which is standard of care. The problem noted was the lack of radiological confirmation of ETT position in patients referred directly from the operation table (where X-ray facilities should be available) and obviously, those from scene, while the lack of cuff pressure monitors as standard of care in many hospitals as well as prehospital, mainly due to apparent cost issues, was worrying. Literature has established the safe tube-tip position as 2–3 cm above the carina to avoid inadvertent right mainstem intubation or supra-glottic slip.⁹

The issue of cuff pressure manometers is one of concern, as this is taught at the paramedic training facilities as the standard of care [personal communication Raveen Naidoo, Head – Durban University of Technology, EMC Program], yet most services do not carry the device, which is a re-usable manometer [informal discussions with local practitioners from various public and private services]. The alternative method taught is a defined volume of air adjusted to the size of the ETT [informal discussions with local practitioners], which has also been proven inaccurate.^{20–22} The challenge is apparently one of cost, with prices quoted between ZAR 350 (single use) and in excess of ZAR 3000 (re-usable), depending on the type and manufacturer. [internet-search by lead author, 20 June 2015]. The fact that these devices are also not standard of care in the operation room remains concerning.¹⁰

Even in the ICU there appears to be a general apathy about the use of manometry and the need for appropriate cuff pressure settings.^{10,11,23,24} Using automated pressure-monitors seem to have the most patient-friendly outcomes and in a before-after trial had a statistically significant improvement in pressure-within normal range compared to intermittent measurement.¹¹ Similar findings in a recent local study suggest

Table 1 Patient demographics and variables collected ($n = 65$ unless indicated otherwise).

Variable				
Age	Median: 30 years	Range: 3–79 years	IQR: 23–48	
Sex	Male: 51 (78%)	Female: 14 (22%)		
Mechanism of injury	Motor vehicle related: 54 (83%)	Gunshot: 3 (5%)	Blunt assault: 6 (9%)	Other: 2 (3%)
Origin of patient	Scene: 28 (43%)	Emergency Centre: 8 (12%)	Theatre: 5 (8%)	Ward/ICU: 24 (37%)
Tube position	Correct: 51 (78%)	Too shallow: 1 ^a (2%)	Too deep: 7 (11%)	Out: 6 ^b (9%)
Intubator	Paramedic: 31	Medical Officer: 33	Registrar: 1	Other: 0
Length of intubation	0–4 h: 39 (60%)	4–12 h: 19 (29%)	12–24 h: 5 (8%)	> 24 h: 2 (3%)
Cuff pressure ranges (cm H ₂ O) ($n = 61$)	0–19: 1 (2%)	20–30: 12 (18%)	31–119: 34 (52%)	> 120: 14 (22%)
Complications ($n = 9$)	Aspiration: 2	Large air leak: 4	Oesophageal tube: 1	Lung collapse: 2

^a Glottic.

^b One Oesophageal and the rest supraglottic.

Table 2 Comparison of scene versus hospital transfer cuff pressures.

Intubation location	Scene of injury	Facility	<i>P</i> -values
Median pressure and interquartile range (cm H ₂ O)	70 (60–>120)	60 (24–90)	$p < 0.001$
Percentage in acceptable cuff pressure range	11%	27%	$p = 0.04$

the ICU population may be best served by continuous monitoring, or at least 4-hourly intermittent monitoring.^{18,25}

Numerous studies have shown that palpation of the pilot-balloon has no correlation with the actual pressure in the cuff and the sensitivity is around 50% in most studies.^{10,15,23,26} While this is a well-known fact, few prehospital, emergency centre or anaesthesia services use cuff-manometry as the standard of care. Studies in paramedic systems have consistently demonstrated cuff over-inflation in services not using routine cuff-pressure monitoring and part of the challenge lies in the varied recommended range of pressures that are considered acceptable (between 20 and 45 cm H₂O).^{15,21,23,27,28}

On balance, current evidence suggests that the MOV to obviate air-flow past the cuff, up to a maximum pressure of less than 25 cm H₂O, is probably the safest practice to minimise high ETT cuff pressures when a manometer is unavailable. However, the ability to ventilate and the prevention of aspiration must take precedence over cuff pressure, but then requires continual vigilance.¹⁰ Our own practice is to use a pressure of 1 cm H₂O above the peak inspiratory pressure on the ventilator, adjusted as needed during the weaning process, thus avoiding a leak, but limiting cuff pressure to the minimum required level.

Comparing the results of this study with previous publications it is pertinent to note that 78% of patients had pressures above the accepted range, which is far higher than that found by Ranaweera (23%) in ICU patients, while similar to Bernon (70%) in emergency patients in Cape Town, and Harm (68%) in a physician-staffed helicopter emergency medicine service (HEMS).^{15,23,29} Table 3 shows the recent published incidence of excessive cuff pressures.

ETT position problems in our cohort occurred less commonly with 80% in the correct place, in keeping with the current evidence, which suggests that tube-position problems occur in between 3% and 15% of intubated patients and may be partly dependent on the method of securing the tube.^{30–32} The optimal position of the tube is well described and can be clinically or radiologically determined.⁹ It is essential to note, however, the significant consequences of tube displacement or malposition, including aspiration or lung collapse, not to mention inadequate oxygenation, the main goal of intubation in the first instance. This may be ameliorated by routine chest X-ray after placement, which is standard of care in hospital.³³

There remain a number of limitations to this study, namely that it is a single-centre prospective comparative convenience-

Table 3 Comparison of recent studies of cuff pressure levels above recommended norms.

Study	Prehospital > 30 cm H ₂ O (%)	Hospital/Theatre/ICU > 30 cm H ₂ O (%)	Study location and setting
Sengupta	–	73	Intra-operative, USA
Svenson	77	–	EC and EMS Helicopter, USA
Galinski	69	82	Prehospital, France
Bernon	70	23	EC versus Operation Room, South Africa
Harm	68	–	EMS Helicopter, Switzerland
Ranaweera	–	23	ICU, United Kingdom
Current study	89	71	Pre- and in-hospital, South Africa

sample over a short time period, with no long-term clinical follow-up of survivors to determine the long-term consequences in the patient cohort under review. It may therefore be difficult to generalise the findings to other settings, despite the concern that this is a general phenomenon.

Conclusion and recommendations

Neither prehospital, nor in-hospital practitioners are adept at clinically assessing ETT-cuff pressure and are still likely to place a significant number (about 20%) of ETT's either too deep or too shallow. The results of these errors may prove disastrous.

Given the disparate ETT cuff-pressures and misplacement issues identified in this study it is essential that cuff-pressure monitoring becomes standard of care in prehospital and in-hospital trauma management and that cost-efficient monitoring devices be developed. For the in-hospital patient, X-ray confirmation of the correct ETT position and regular (4-hourly) cuff-pressure recording, with adjustment as needed, is likely to reduce post-admission morbidity and mortality. We recommend that the ideal pressure in patients who remain difficult to ventilate be adjusted to 1 cm H₂O above the peak pressure to prevent air leaks, but that it also be regularly adjusted as patient condition improves.

Dissemination of results

Results from this study were shared with staff and Ems personnel at IALCH Trauma Unit emergency centre ward rounds through ongoing educational initiatives. The results were also presented in an educational article in FIRE-Africa and in formal lectures to DUT/KZN-COEC students.

Author contributions

T.C.H. and D.J.J.M. conceived the study, T.C.H. and M.F. collected the data, T.C.H., M.F. and D.J.J.M. all co-wrote and reviewed the paper prior to submission and T.C.H. handled the queries and revisions.

Conflict of interest

T.C.H. is on the editorial board of the African Journal of Emergency Medicine. He was not involved in the editorial work-flow of this paper. The authors declare no other conflict of interest.

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