

# Endotracheal Cuff Pressures in Ventilated Patients in Intensive Care

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## Abstract

**Aim:** To describe the endotracheal cuff pressure ( $P_{\text{cuff}}$ ) measurements of patients receiving ventilation via endotracheal tubes in an Intensive Care Unit (ICU).

**Method:**  $P_{\text{cuff}}$  were measured daily using a cuff tonometer and the pressure then adjusted to  $<30$   $\text{cmH}_2\text{O}$  in patients ventilated in the ICU, over fifteen months.

Data collected were demographics, the location where intubation occurred, and airway pressures when available (PEEP, peak, and plateau). Data was analysed using Kruskal-Wallis and Dunn's Multiple Comparison Test.

**Results:** 1073 data sets were collected from 199 intubated ventilated adults. Of all  $P_{\text{cuff}}$  measured 15.7% (169) exceeded 30  $\text{cmH}_2\text{O}$ . The first  $P_{\text{cuff}}$  measurements made during ICU stay had median pressure 30  $\text{cmH}_2\text{O}$  (IQR 23.5-40) and 34.5% (68) exceeded 30  $\text{cmH}_2\text{O}$ .

Median  $P_{\text{cuff}}$  of patients admitted following intubation in the Operating Theatre (OT) were 26  $\text{cmH}_2\text{O}$  (IQR 20-37), those via Emergency Department (ED) were 32  $\text{cmH}_2\text{O}$  (IQR 28-57), and those intubated in ICU were 28  $\text{cmH}_2\text{O}$  (IQR 22-34.25).  $P_{\text{cuff}}$  of patients intubated in OT differed significantly from ED patients, as did ICU patients compared to ED ( $p < 0.005$ ). ICU and OT patients did not differ.

**Conclusion:**  $P_{\text{cuff}}$  measurement is not routine at intubation. Described complications of elevated  $P_{\text{cuff}}$  include cuff herniation, vocal cord damage, tracheal mucosal ischaemia, and airway obstruction. Unrecognised elevated  $P_{\text{cuff}}$  is common, with a higher incidence in ED than ICU or OT. Skilled intubation assistance from anaesthetic technicians is routine in OT, common in ICU, but less frequent in ED, and may influence the initial  $P_{\text{cuff}}$ .

**Key words:** Endotracheal cuff, tracheal damage, pressure, intubation, emergency, anaesthetic technician.

## Introduction

There are well over 50,000 patients who receive ventilation via an endotracheal tube in the Intensive

Care Units (ICUs) in Australia and New Zealand every year [1]. Almost all episodes of invasive ventilation in adults are associated with inflation of endotracheal cuff. While monitoring of the cuff pressure has been recommended during anaesthesia this has not been reflected in any of the minimum standards documents [2]. Endotracheal tubes placed in the Operating Theatre (OT) are usually in situ for a matter of hours, while endotracheal intubation in ICU is more prolonged, and thus the risk of time dependent sequelae is increased. If the  $P_{\text{cuff}}$  is excessively elevated the cuff has the

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potential to herniate or to cause direct damage through ischemia of the tracheal mucosa.

## Method

Over the period of fifteen months we collected endotracheal data from patients with endotracheal tubes in the ICU. It was not standard practice to use a pressure measuring device in the OT, Emergency Department (ED), ICU or other area at the time of intubation. When intubation was conducted in OT a trained anaesthetic technician was in attendance and routinely inflated the endotracheal cuff using a syringe. In other locations a trained anaesthetic technician was not uniformly available but whenever present provided this service. Assistance at intubation in these circumstances was provided by registered nurses, with variable experience in assisting intubation.

On the morning following ICU admission, the endotracheal cuff pressures ( $P_{\text{cuff}}$ ) were measured using an endotracheal cuff manometer (Portex, Germany) by the Intensive Care anaesthetic technician. At this time,  $P_{\text{cuff}}$  were adjusted to be within the recommended guideline limits of less than 30 cmH<sub>2</sub>O. The peak, plateau, mean and end-expiratory airway pressure when available were measured directly from the ventilator. Data from patients <15 years was not included. Age, sex, and the unit/site where intubation occurred were recorded. All cuff pressure measurements and adjustments were repeated daily.

Data was analysed using Kruskal-Wallis and Dunn's Multiple Comparison Test was performed using GraphPad InStat version 3.0a for Macintosh (GraphPad Software, San Diego California USA, [www.graphpad.com](http://www.graphpad.com)) on a Macintosh Computer (Cupertino, California, USA).

## Results

Over the 60 weeks 1073 data sets were collected from 199 intubated patients. The median age was 59.5 years (IQR 46-72), with 55% being male patients.

Cuff pressure measurement were taken in all 199 patients. PEEP, peak airway pressure, plateau

pressure and mean pressures were available in 199, 189, 133, and 189 patients respectively. Summary data of all cuff, peak, plateau and end-expiratory airway pressure are recorded in **Figure 1**. Initial pressures measured in ICU are displayed in **Figure 2**.

Of all  $P_{\text{cuff}}$  measured 15.7% (169) exceeded 30 cmH<sub>2</sub>O. The first  $P_{\text{cuff}}$  measurements made during ICU stay (day 1 of measurement) had median pressure 30 cmH<sub>2</sub>O (IQR 23.5-40) and 34.5% (68) exceeded 30 cmH<sub>2</sub>O.

Of the 199 patients, 28 were admitted ventilated from the OT, 51 ventilated from ED and 112 were intubated in ICU. Eight patients were intubated in other institutions.

Median  $P_{\text{cuff}}$  of patients admitted following intubation in the OT were 26 cmH<sub>2</sub>O (IQR 20-37), those via ED were 32 cmH<sub>2</sub>O (IQR 28-57), and those intubated in ICU were 28 cmH<sub>2</sub>O (IQR 22-34.25).

Patients undergoing intubation in the OT, ED and ICU, 38%, 53%, and 27% respectively had pressures above 30 cmH<sub>2</sub>O. Results are displayed in **Figure 3**. Cuff pressures lower than 15 cmH<sub>2</sub>O were found in 14 patients, and four were less than 10 cmH<sub>2</sub>O.

$P_{\text{cuff}}$  of patients intubated in OT differed significantly from ED patients, as did ICU patients compared to ED ( $p < 0.005$ ). ICU and OT patients did not differ significantly (**Table 1**).

**Airway pressures:** Of all the initial  $P_{\text{cuff}}$  measurements results 189 Peak, 133 plateau, and 189 Mean and 198 Positive end expiratory pressures were recorded. In 9 patients (4.8%) and 3 (2.5%) of Peak and plateau pressures respectively exceeded 30 cmH<sub>2</sub>O.

There were 245 adult intubated patients in the unit during the period. Reason for non collection of data included extubation or death prior to measurement being made, and absence of the anaesthetic technician for data collection.

## Discussion

Cuff pressure measurement is not included

in the minimum standards for the safe provision of anaesthesia and is not routinely used in many ICU [2,3]. However the complications of high cuff pressures include cuff herniation, vocal cord damage or paralysis and tracheal mucosal ischaemia, which may result in airway obstruction [4-7].

Endotracheal tube pressures required to occlude the airway is typically under 20 cmH<sub>2</sub>O [8]. Cuff pressures greater than 30 cmH<sub>2</sub>O (22 mmHg) compromises mucosal blood flow, while tracheal mucosal blood flow is totally obstructed at pressures greater than 50 cmH<sub>2</sub>O (37 mmHg) [9]. However, mucosal surface pressure and in intra-luminal balloon pressure may differ [10]. A large proportion of our patients had pressures exceeding the recommended threshold and a quarter had P<sub>cuff</sub> 40 cmH<sub>2</sub>O or more.

Although longer term effects are rare, there are effects from short term intubation at high cuff pressures [11]. Our proportion of patients having an initial elevated P<sub>cuff</sub> above 30 cmH<sub>2</sub>O similar to that described by Sengupta and colleagues in patients undergoing general anaesthesia in OT but considerably a lower than the 77% experienced by Jaber and colleagues in a French intensive care [12,13]. Interestingly the figures obtained by Jaber's groups one month (24%) and three years (31%) after implementing a P<sub>cuff</sub> measurement protocol were more closely aligned to our figures [13]. Increasing awareness the relatively high frequency of over-inflated cuffs and educating staff of the dangers of elevated pressures may reduce the incidence in the future.

Leaks may occur during the high inspiratory driving pressures that are sometimes required when there is airflow restriction. The pressure exerted against the cuff, while lower than the peak airway pressure, may be higher than the plateau pressure measured during inspiratory hold, particularly if there is lower airway obstruction. As result some volume of the inspiratory flow may leak out from the airway, and as the airflow is outward is not associated with aspiration and inward flow. Leak at low inspiratory pressures may indicate inadequate seal, or low P<sub>cuff</sub> which will increase the risk of aspiration. A possible explanation of the elevated P<sub>cuff</sub> in some patients is

that there is a perceived need to prevent all leaks, and thus P<sub>cuff</sub> is increased by injection of additional volume until the leak disappears. Protective lung ventilation strategies have been standard therapy in our unit and the ventilation parameters usually comply with recognized pressure and tidal volume targets [14]. Consequently very few of patients received plateau pressures exceeded 30 cmH<sub>2</sub>O.

All ventilated patients transferred from the ED would have been intubated in an emergency situation often without the assistance of trained personnel, and some would have been intubated outside the hospital by paramedical or medical staff. The intubated in the ED or in the ICU had a trained anaesthetic technician present only on some occasions. In contrast, anaesthetists performed all intubations in the OT with assistance from a trained anaesthetic technician. While it ultimately the medical practitioner performing the intubations has the responsibility for the ensuring an appropriate cuff pressure, the aid of skill personnel are likely to reduce the error or omission rate.

There may be other factors that increase the incidence of elevated of P<sub>cuff</sub> including the difficulty of the intubation, the urgency of the need to secure the airway and the experience of the intubating clinician. Emergency situations when the priority at intubation are securing the airway and preventing further aspiration are more likely to result in elevated pressures [15]. However, the longer-term consequences of elevated tracheal cuff pressures including tracheal damage from ischaemia and stenosis. The clinician who is intubating the patient may not appreciate the potential for damage resulting from excessive cuff pressure, and the immediate priority is one of securing the airway rather than longer-term problems.

Clinical cuff pressure estimation can be difficult, and in those who do not routinely intubate, the pressure generated may be excessive. Hoffman and colleagues found pressures average 93 cmH<sub>2</sub>O after inflation by experienced ED physicians [16].

A variety of ways of assessing appropriate cuff volume have been suggested including using carbon dioxide levels to detect leaks, and a variety of pneumatic

systems to adjust cuff pressures are available [17-21]. However the incidence of complications has not been influenced by such innovations [21]. Simple inflation with a syringe and regular checking with a manometer are sufficient to ensure adequate cuff pressures are maintained.

Aspiration of gastric contents is a common occurrence and the subsequent pneumonitis are a risk in ventilated patients particularly in those in which antibiotics are not utilized [22]. In normal circumstances the head of fluid above an endotracheal cuff would be limited to a few centimetres of water, and therefore the pressures recommended as inflation pressures if transmitted across the membrane would be sufficient to exclude any matter descending down the trachea. However mechanics of the trachea mean that no amount of pressure with the current membranes is able to prevent material from above the cuff passing to below the cuff.

At present large-volume, low-pressure ETT cuffs are widely used in most institutions. Cuff pressures below a critical threshold may increase the risk of aspiration of upper airway debris. This may in turn increase respiratory problems from aspiration pneumonitis or ventilator associated pneumonia [22]. Studies indicate that at pressures ranging from 10-30 cmH<sub>2</sub>O consistently low volumes of fluid are aspirated [23]. Prevention of aspiration is not entirely prevented ensured even with pressures in this range, as movement and imperfections in the cuff seal may result in tracheal soiling [24]. Maintaining a pressure that isolates the respiratory tract without causing tracheal damage is the goal in any intubated patient attempting to balance the risk of mucosal damage and the risk of VAP. In our group, only 4 patients had P<sub>cuff</sub> less than 10 cmH<sub>2</sub>O. Further research into the composition of tracheal cuff balloons, the cuff pressure required to prevent aspiration and the effect upon pneumonia rate and outcome is warranted.

However very few papers describe the measurement or monitoring of cuff pressures. If aspiration, as a complication of tracheotomy or endotracheal tubes, is of concern, then ensuring adequate cuff pressures through monitoring would be

a worthwhile intervention. Cuff measurement is simple and easy to implement, there are few complications associated with titration of the pressure. Endotracheal cuff pressure should be set to balance the risk of mucosal damage and the risk of VAP.

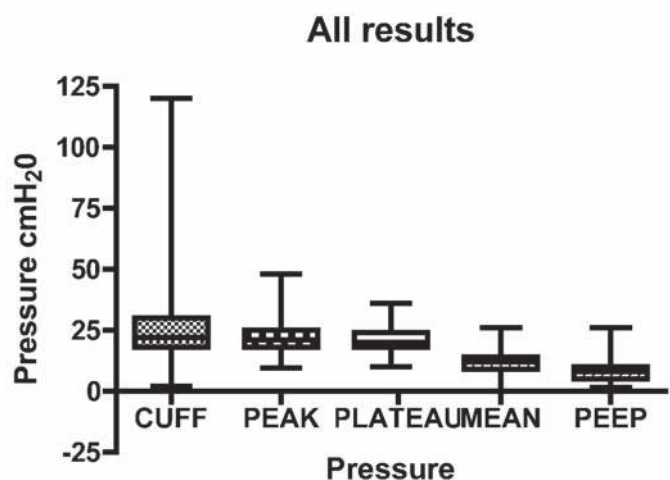
## Conclusion

The endotracheal cuff pressure is frequently very high in the patient ventilated in intensive care, particularly in those who are admitted from the emergency situations. Unrecognised elevated P<sub>cuff</sub> has a higher incidence in ED than ICU or OT. Skilled intubation assistance from anaesthetic technicians is routine in OT, common in ICU, but less frequent in ED, and may influence the initial P<sub>cuff</sub>. Presence of trained personnel in assistance during the intubation may reduce the frequency of high pressure, and routine checking of these pressures is required to ensure they are maintained in the recommended range.

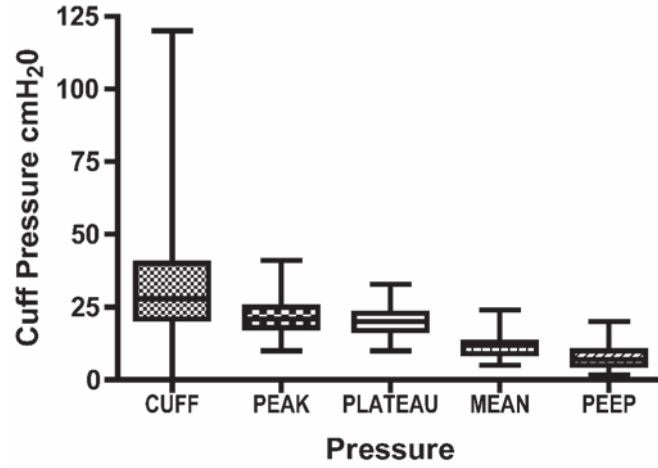
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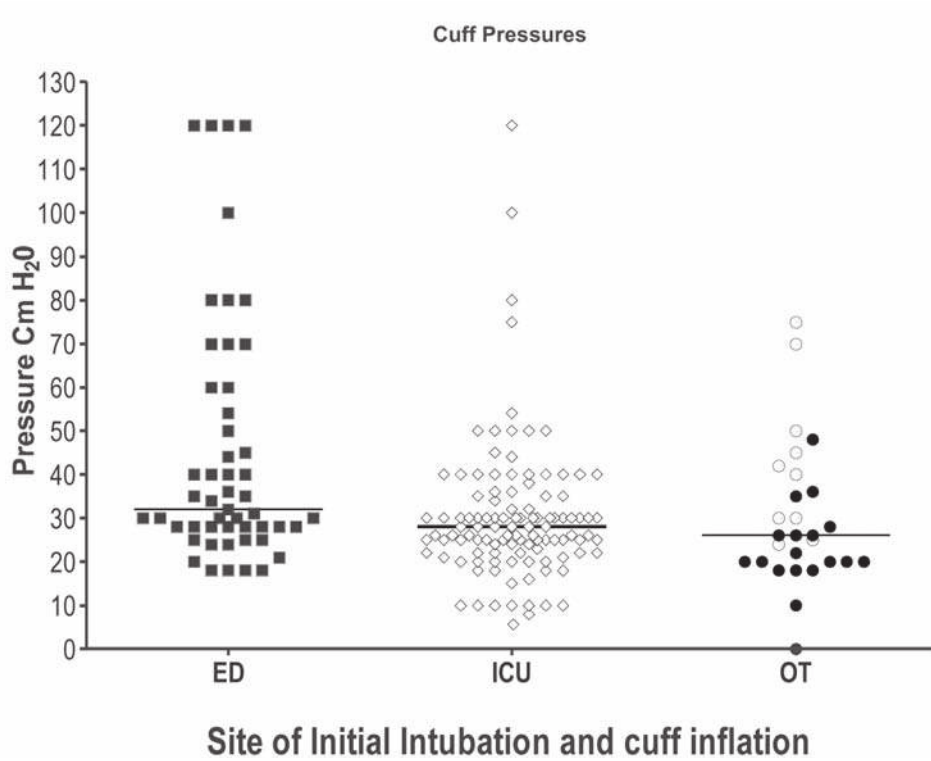
**Figure 1.** ALL CUFF AND VENTILATION PRESSURES OF PATIENTS WHILE IN INTENSIVE CARE



**Figure 2.** CUFF AND VENTILATION PRESSURES OF PATIENTS ON FIRST MEASUREMENT IN INTENSIVE CARE



**Figure 3.** DEPARTMENT WHERE PATIENT WAS FIRST INTUBATED



**Table 1.** PATIENTS GROUPED BY SITE (ED, ICU AND OT) OF INTUBATIONComparison between groups of the initial P<sub>cuff</sub> measurements.

Parameter	Value	ICU
Dunn's Multiple Comparison Test	Difference in rank sum	P value
ED vs ICU	31.29	P < 0.01
ED vs OT	36.21	P < 0.05]
ICU vs OT	4.920	P > 0.05

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