

Effect of Head Position Change on Endotracheal Tube Cuff Pressure in Mechanically Ventilated Patients Admitted in Intensive Care Units of a Tertiary Care Hospital: A Quasi-Experimental Study

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Abstract

Background: Endotracheal tube (ETT) cuffs seal the airway and permit safe positive-pressure ventilation, but the seal is only protective when intracuff pressure is kept within the recommended 20-30 cmH₂O band. Head and neck movement, a routine part of intensive care nursing, has been reported to alter this pressure, yet Indian evidence on the subject remains scarce. **Objectives:** To assess pre-interventional ETT cuff pressure in the neutral head position, to assess post-interventional cuff pressure after each of six head positions, and to compare pre- and post-interventional cuff pressure among mechanically ventilated patients. **Methods:** A quantitative, quasi-experimental, one-group pre-test-post-test design was used. Thirty orally intubated, mechanically ventilated adults in the intensive care units of a tertiary care teaching hospital in Ludhiana, Punjab, were enrolled by convenience sampling. Baseline (neutral position) cuff pressure was recorded with a calibrated aneroid cuff-pressure manometer after adjusting the cuff to approximately 25 cmH₂O. The head was then sequentially repositioned into anterior flexion, hyperextension, left lateral flexion, right lateral flexion, left rotation, and right rotation, each held for five minutes, with cuff pressure and selected physiological variables (heart rate, respiratory rate, oxygen saturation, minute ventilation, peak airway pressure) recorded after every position. Data were analysed with descriptive statistics, the paired t-test, and one-way ANOVA at a 0.05 level of significance. **Results:** Mean baseline cuff pressure was 25.23 +/- 1.278 cmH₂O. Anterior flexion produced the largest and most consistent rise, to 32.47 +/- 3.137 cmH₂O (t = 12.674, p = 0.000), followed by left lateral flexion, 28.87 +/- 4.883 cmH₂O (t = 3.840, p = 0.001). Hyperextension, right flexion, left rotation, and right rotation did not differ significantly from baseline (p > 0.05). One-way ANOVA confirmed an overall significant effect of head position on cuff pressure (F = 9.709, p = 0.000). Heart rate, respiratory rate, oxygen saturation, minute ventilation, and peak inspiratory pressure showed no clinically meaningful or consistent change across positions. **Conclusion:** Head position materially affects ETT cuff pressure, with anterior flexion and, to a lesser extent, lateral flexion carrying the greatest risk of unrecognised overinflation above the safe ceiling of 30 cmH₂O. Cuff pressure should be re-verified after every change in head position, particularly flexion, to protect the tracheal mucosa and reduce the risk of ventilator-associated pneumonia and other airway complications.

Keywords: endotracheal tube; cuff pressure; head position; mechanical ventilation; intensive care unit; nursing

Introduction

Mechanical ventilation is among the defining technologies of modern critical care, sustaining gas exchange in patients whose own respiratory effort has failed. Since the ARDSNet investigators demonstrated the mortality benefit of a lung-protective ventilation strategy, clinical and research interest in ventilator management has grown steadily (Acute Respiratory Distress Syndrome Network et al., 2000). The technology itself, however, traces back much further, to the iron-lung era of the early twentieth century and to the polio epidemics that forced its rapid refinement (Slutsky, 2015; Geddes, 2007). The Copenhagen polio outbreak of 1952 in particular is credited with catalysing the shift from negative-pressure to positive-pressure ventilation and, indirectly, with the birth of the modern intensive care unit (Slutsky, 2015). Positive-pressure ventilation, however, is only deliverable through a secured, sealed airway, and it is this requirement that gave the endotracheal tube its central place in critical care practice.

The cuffed endotracheal tube (ETT) is designed to occlude the space between the tube and the tracheal wall, permitting positive-pressure breaths to be delivered without loss of volume and reducing the risk that oropharyngeal or gastric secretions pooling above the cuff will be aspirated into the lower airway (Szmuk et al., 2008; Haas et al., 2014). Contemporary tubes use high-volume, low-pressure polyvinyl chloride (PVC) cuffs that distribute pressure over a wider mucosal surface than the earlier low-volume, high-pressure designs (Alvarado & Panakos, 2020). Distributing the pressure, however, does not remove the need to control it: the cuff still exerts a circumferential force on the tracheal mucosa, and that force must be kept within a narrow physiological window if the airway is to be protected without being injured.

The internationally accepted safe range for ETT cuff pressure is 20 to 30 cmH₂O (Maddumage et al., 2017). Below 20 cmH₂O the seal becomes incompetent, allowing subclinical aspiration of contaminated subglottic secretions around the cuff, a recognised precursor of ventilator-associated pneumonia (VAP) (Khalil et al., 2018). Above 30 cmH₂O, the cuff begins to compress the capillary bed of the tracheal mucosa; because mean capillary perfusion pressure in the trachea is estimated at approximately 25-35 cmH₂O, pressures above this threshold impede mucosal blood flow, and pressures exceeding 50 cmH₂O abolish it altogether (El-Orbany & Salem, 2013). Sustained ischaemia of this kind underlies a well-documented spectrum of complications, ranging from sore throat, hoarseness, and mucosal ulceration to tracheal stenosis, tracheomalacia, and, in extreme or prolonged cases, tracheo-oesophageal or tracheo-innominate fistula (Guyton et al., 1991; Mehta & Myat, 1984). Because these injuries accumulate silently over the course of a ventilator stay, cuff pressure is rightly regarded as a routine, non-negotiable nursing observation rather than a one-off procedural step performed only at the time of intubation.

What makes cuff pressure difficult to keep stable in practice is that it is not a fixed quantity fixed once the tube is placed; it drifts in response to a range of patient, tube, and care-related factors. Positive-pressure ventilation itself, breathing circuits enriched with nitrous oxide, altitude change during air transport, and pathological processes such as bronchospasm or laryngeal oedema have all been shown to raise cuff pressure over time (Tu et al., 1999; Bassi et al., 2010). Conversely, sedation, neuromuscular blockade, a fall in core body temperature such as occurs during cardiopulmonary bypass, and simple passive leakage of air from the cuff over time tend to lower it (Girling et al., 1999; Inada et al., 1995; Sole et al., 2003). Superimposed on all of these influences is a variable that nurses manipulate many times each shift for entirely unrelated reasons: the position of the patient's head and neck.

Head and neck repositioning is one of the most frequent interventions performed on a ventilated patient in the intensive care unit. It occurs during routine hygiene care, oral suctioning, tube fixation checks, feeding, physiotherapy, and simply when a patient is turned to relieve pressure areas or to improve comfort. Anatomically, flexion of the neck shortens the visible length of trachea above the carina and draws the fixed endotracheal tube tip caudally, effectively advancing it relative to the tracheal wall; because the tube is a rigid cylinder inserted into a curved and mobile airway, this migration compresses the cuff against a narrower segment of trachea and raises the pressure recorded at the pilot balloon (Kako et al., 2014). Extension has the converse anatomical effect, lengthening the exposed trachea and tending to withdraw the tube slightly, which in several studies has been associated with a fall in cuff pressure or the onset of an audible air leak (Inoue et al., 1998). Lateral flexion and rotation act through a combination of tube torsion and asymmetric tracheal wall contact, and their effect on pressure has been reported as more variable across studies than that of sagittal-plane flexion and extension (Lizy et al., 2014; Okgun Alcan et al., 2017).

Despite very little of this being new information in principle, awareness of the magnitude of the effect, and of which specific positions carry the greatest risk, remains patchy at the bedside. Nazari et al. (2020) conducted a quasi-experimental study that is directly comparable in design to the present study and found that cuff pressure increased in all six head positions tested, with the largest rises recorded during anterior flexion and left rotation ($p < 0.001$); in a substantial proportion of their patients the resulting pressure exceeded the 30 cmH₂O ceiling. Similar patterns, though with differing magnitudes and differing 'worst' positions, have been reported from paediatric operating-theatre populations (Kako et al., 2014), general surgical patients undergoing laparoscopy (Rosero et al., 2018), and mixed medical-surgical ICU cohorts undergoing routine nursing care (Beccaria et al., 2017). Almost all of this literature, however, originates from outside India, and practice variables such as tube brand, cuff material, fixation technique, sedation protocol, and nursing staffing ratios differ enough between health systems that findings cannot simply be transplanted from one setting to another.

This gap provided the impetus for the present study. Investigating the relationship between head position and cuff pressure in an Indian tertiary care ICU setting was expected to generate context-specific evidence that could inform local nursing protocols for airway care, complementing rather than merely repeating the international literature. The specific research problem, aim, objectives, operational definitions, and hypothesis that guided the study are set out below.

Problem Statement

A study to assess the effect of head position change on endotracheal tube cuff pressure in mechanically ventilated patients admitted to intensive care units of a selected tertiary care hospital, Ludhiana, Punjab.

Aim

To assess the effect of head position change on endotracheal tube cuff pressure in mechanically ventilated patients admitted to intensive care units.

Objectives

1. To assess the pre-interventional endotracheal tube cuff pressure before head position change among mechanically ventilated patients.

2. To assess the post-interventional endotracheal tube cuff pressure after each head position change among mechanically ventilated patients.
3. To compare pre- and post-interventional endotracheal tube cuff pressure among mechanically ventilated patients.

Hypothesis

H1 (research hypothesis): Head position change has a statistically significant effect on endotracheal tube cuff pressure in mechanically ventilated patients admitted to intensive care units (tested against the null hypothesis of no effect, at the 0.05 level of significance).

Operational Definitions

Head position change: The sequential repositioning of the patient's head into six defined positions -- anterior flexion, hyperextension, left lateral flexion, right lateral flexion, left rotation, and right rotation -- each maintained for five minutes, following a five-minute baseline in the neutral position.

Endotracheal tube cuff pressure: The pressure generated by air within the ETT cuff, required to seal the airway for effective ventilation, measured with a calibrated cuff-pressure manometer in all six head positions and expressed in cmH₂O; the accepted normal range is 20-30 cmH₂O.

Mechanically ventilated patients: Orally intubated adult patients receiving ventilatory support for life-threatening illness or injury in the intensive care units of the study hospital.

Delimitation

The study was delimited to 30 mechanically ventilated patients admitted to the intensive care units of the study hospital during the data collection period.

Review of Literature

A structured review of literature was undertaken to situate the present study within existing evidence and to justify its design. Sharma (2014) describes a literature review as a broad, structured, and critical appraisal of published and unpublished material bearing on a research problem, while Polit and Hungler (1999) frame it as the systematic identification, location, and synthesis of written material on a topic. Guided by these definitions, the review was organised into two sections: studies describing complications arising from abnormal (either excessively high or excessively low) ETT cuff pressure, and studies examining the specific effect of head or body position change on cuff pressure in mechanically ventilated or anaesthetised patients.

Studies Related to Complications of Abnormal Endotracheal Tube Cuff Pressure

Several studies converge on the finding that ETT cuffs are frequently, and often silently, overinflated. Rosero et al. (2018), studying patients undergoing pelvic laparoscopic surgery, found that 89% of cuffs were already overinflated (>30 cmH₂O) immediately after intubation, and that cuff pressure rose further, from a mean of 29.6 cmH₂O to 35.6 cmH₂O, with the increase in intra-abdominal and airway pressure produced by pneumoperitoneum ($p < 0.0001$). Table inclination and a 1:1 inspiratory-to-expiratory ratio were independently associated with further pressure increases. In a complementary experimental study, Asai et al. (2014) demonstrated that the very act of connecting a cuff inflator to the pilot balloon to check

pressure caused it to fall by an average of 6.6 cmH₂O, with more than two-thirds of measurements dropping below 20 cmH₂O immediately afterward -- a sobering reminder that the measurement process itself can introduce error and that smaller tubes and pyriform cuffs are particularly susceptible.

El-Orbany and Salem (2013) reviewed the clinical consequences of ETT cuff leaks, noting that presentations range from an audible bubbling sound to frank ventilatory failure, and that causes include cuff underinflation, cephalad tube migration, and mismatch between tube and tracheal diameter; the authors argued that most leaks can be corrected without tube replacement if identified early, underscoring the value of routine cuff pressure surveillance. Physiological work by Guyton et al. (1991) and by Mehta and Myat (1984) established the anatomical and haemodynamic basis for the 20-30 cmH₂O safe range, showing that tracheal capillary perfusion pressure sits close to this band and is progressively compromised as cuff pressure rises above it. Tu et al. (1999) and Bassi et al. (2010) extended this picture by identifying nitrous oxide diffusion and altitude change during aeromedical transport, respectively, as clinically important causes of unplanned cuff pressure elevation, while Girling et al. (1999) and Inada et al. (1995) linked neuromuscular blockade, sedation depth, and hypothermia during cardiopulmonary bypass to unplanned pressure reduction. Sole et al. (2003, 2009) and Khalil et al. (2018) each documented that pressures drift out of the safe range between scheduled checks and after routine nursing procedures, reinforcing the case for more frequent, position-aware monitoring rather than fixed-interval checks alone.

Studies Related to Head Position Change and Endotracheal Tube Cuff Pressure

The second body of literature addresses the present study's central question directly: does changing head or neck position alter ETT cuff pressure, and if so, by how much and in which direction? Nazari et al. (2020), in the quasi-experimental study most comparable in design to the present one, followed mechanically ventilated ICU patients through the same six head positions used here and found that cuff pressure rose significantly in every position, with the largest rises during anterior flexion and left rotation ($p < 0.001$); a substantial proportion of patients exceeded the 30 cmH₂O ceiling in these positions. Working in a surgical population, Kara et al. (2020) reported that intracuff pressure rose significantly after both left and right neck rotation and, more markedly, after neck extension combined with rotation, with post-hoc comparisons confirming that extension by itself was already sufficient to produce a significant rise from the neutral baseline.

Choi et al. (2017), in a randomised comparison of tapered-cuff and cylindrical-cuff tubes during middle-ear surgery, found that lateral head rotation raised cuff pressure significantly more with the tapered design (11.9 +/- 2.3 cmH₂O) than with the cylindrical design (6.0 +/- 1.9 cmH₂O), and that the incidence of pressures above 30 cmH₂O was far higher with the tapered cuff -- evidence that cuff geometry, and not head position alone, modulates the size of the effect. Beccaria et al. (2017) examined the impact of routine nursing care rather than a specific positional manoeuvre, finding that most of seven observed nursing procedures produced a statistically significant change in cuff pressure, with the effect most pronounced in the morning shift and least pronounced in the evening. Delorenzo et al. (2017), in a systematic review of ETT cuff pressure during helicopter transport, identified only two eligible prospective studies but found that both reported mean cuff pressure increases (23 and 33.9 cmH₂O respectively) that frequently exceeded the critical tracheal mucosal perfusion pressure, implicating vibration, altitude change, and patient repositioning during transfer as compounding factors.

In a large positional study, Okgun Alcan et al. (2017) recorded 400 cuff pressure measurements across 25 patients and 16 positions, finding that nearly half of all readings (47.3%) exceeded 30 cmH₂O and that

mean pressure rose from a baseline of 25 cmH₂O to 32.59 $\pm$ 4.08 cmH₂O after repositioning (Friedman test, $p = 0.0001$) -- a magnitude of overinflation strikingly close to that recorded for anterior flexion in the present study. Paediatric evidence tells a broadly similar story: Olsen et al. (2016) found that intracuff pressure rose in 54.8% of children repositioned for adenotonsillectomy, and Kako et al. (2014) reported that 68.1% of 1,000 intracuff pressure readings taken across repositioning manoeuvres in 200 paediatric patients showed an increase, with flexion again identified as the position most reliably associated with a rise and extension the position most often associated with a fall. Kim et al. (2015) and Kako et al. (2015) both demonstrated that cuff shape (tapered versus cylindrical) modifies the magnitude of pressure change after a change from supine to lateral positioning, echoing the tube-design effect described by Choi et al. (2017) above. Lizy et al. (2014), studying a broader set of sixteen body and head positions in critically ill ICU patients, found a significant deviation in cuff pressure with every single position change tested, with 40.6% of measurements exceeding the upper safe limit and considerable within-patient variability -- a finding that anticipated much of what the present study would later confirm in an Indian ICU population. Finally, Tsuboi et al. (2013) and Inoue et al. (1998) provide mechanistic detail relevant to interpreting these positional effects: the former demonstrated that cuff shape modulates susceptibility to nitrous-oxide-driven pressure rise, and the latter showed, in an early and frequently cited experimental study, that flexion reliably produces excessive intracuff pressure while extension produces both pressure loss and audible air leak, attributing both phenomena to tube movement relative to the trachea rather than to any change in cuff volume per se.

Taken together, this literature is remarkably consistent on two points that directly informed the design of the present study: first, that head and neck position materially affects ETT cuff pressure, usually by moving the fixed tube relative to a curved and mobile trachea rather than by any deliberate change in cuff inflation; and second, that anterior flexion is the position most consistently associated with a clinically important rise in pressure, while extension is more often associated with a fall or an air leak. What the literature could not answer, prior to the present study, was whether this pattern would replicate in an Indian tertiary care ICU, where tube brands, fixation practice, sedation protocols, and nursing staffing patterns differ from the mainly Iranian, East Asian, and Western settings in which most of the cited studies were conducted.

Materials and Methods

Research Approach

A quantitative research approach was adopted, consistent with the study's aim of measuring and statistically comparing a physiological outcome (cuff pressure) across defined experimental conditions (head positions).

Research Design

A one-group, pre-test-post-test (quasi-experimental) design was used. Each patient served as their own control: the neutral head position constituted the pre-intervention baseline, and each of the six subsequent head positions constituted a post-intervention observation. This within-subject design controls for inter-patient variability in tracheal anatomy, tube size, and baseline cuff characteristics, all of which would otherwise confound a between-groups comparison.

Research Setting

The study was conducted in the intensive care units (Medical ICU, Pulmonary ICU, Surgical ICU, Stroke ICU, Trauma ICU, and Neurosurgical ICU) of Dayanand Medical College and Hospital (DMCH), Ludhiana, Punjab -- a 1,500-bed tertiary care teaching institution established in 1937 that provides multi-speciality emergency, medical, surgical, and critical care services and trains undergraduate, postgraduate, and super-specialty medical and nursing students.

Target Population

The target population comprised orally intubated, mechanically ventilated adult patients admitted to the above intensive care units who met the eligibility criteria described below.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Orally intubated patients
- Aged 18 years or above
- Able to be placed safely in a supine position
- Sedated to a Richmond Agitation-Sedation Scale (RASS) score of -3 or deeper

Exclusion criteria:

- Decreased mobility of the neck
- History of difficult intubation
- History of neck surgery
- Head injury
- Spinal cord injury
- Upper gastrointestinal bleed
- Morbid obesity (body mass index > 35 kg/m²)
- Any other contraindication to a change in body position, such as unstable haemodynamic status

Sample and Sampling Technique

Thirty mechanically ventilated, orally intubated patients meeting the eligibility criteria were enrolled from the target population using convenience (non-probability) sampling, a method chosen for its feasibility given the fluctuating daily census of eligible, stable, adequately sedated patients across six intensive care units.

Research Variables

The independent variable was head position, operationalised across seven levels: neutral (baseline), anterior flexion, hyperextension, left lateral flexion, right lateral flexion, left rotation, and right rotation. The dependent variable was endotracheal tube cuff pressure, measured in cmH₂O. Heart rate, respiratory rate, oxygen saturation, minute ventilation, and peak inspiratory pressure were recorded as secondary physiological outcomes to assess whether the positional manoeuvres produced any measurable haemodynamic or ventilatory disturbance.

Development and Description of the Research Tool

A structured, investigator-developed tool was used, informed by an extensive review of literature and consultation with critical care physicians, nursing faculty, and clinical experts. The tool comprised two parts. Part A recorded the patient's profile in two sections: Section I captured socio-demographic variables (age, gender, habitat, educational status, religion, marital status, family structure, dietary habits, substance use, occupation, and socio-economic status), and Section II captured the clinical profile (diagnosis, mode of hospital admission, co-morbidities, body mass index, body temperature, duration of hospitalisation and ICU stay, days of intubation, indication for intubation, sedation level, ETT material and characteristics, ventilator mode and settings, and arterial blood gas parameters). Part B was the ETT cuff pressure assessment sheet, on which cuff pressure readings taken with a calibrated cuff-pressure manometer were recorded in the neutral position and after each of the six experimental head positions.

Validity and Reliability

Content validity was established through review by the research supervisor, co-supervisors, and a panel of thirteen subject experts drawn from critical care medicine and nursing education, who evaluated the relevance, clarity, and comprehensiveness of tool items.

Consistent with Polit and Hungler's (1999) definition of reliability as the degree of consistency with which an instrument measures the attribute it is intended to measure, the ETT cuff pressure assessment sheet was tested using an inter-rater method on four patients, with agreement calculated as the number of agreements divided by the sum of agreements and disagreements.

Pilot Study

A pilot study was conducted on four patients in the same intensive care units to establish the feasibility of recruitment, the clarity of tool items, and the practicality of the positioning and measurement protocol. No major modifications were required; minor refinements to wording were incorporated before full-scale data collection.

Intervention and Data Collection Procedure

Following institutional ethical approval, screening, and informed consent, data were collected in March 2022 using a standardised positioning and measurement protocol:

4. Eligible, consenting patients ($n = 30$) were drawn from the target population by convenience sampling.
5. Baseline data, including the socio-demographic and clinical profile, were recorded, and the cuff pressure manometer was connected to establish baseline readings.
6. The head of the bed was set to a 30-degree angle, verified with a protractor, with the patient supine and the head in the neutral position (no rotation, flexion, or extension). This defined the pre-intervention (O1) reading.
7. In the neutral position, cuff pressure was adjusted to approximately 25 cmH₂O and confirmed to be free of an audible air leak; this reading was held and observed for five minutes before proceeding.
8. The cuff pressure manometer remained connected throughout, from the neutral (pre-intervention) reading to the final post-intervention reading, so that no disconnection-related pressure loss (as described by Asai et al., 2014) was introduced into the comparison.

9. The patient's head was then repositioned sequentially into six positions, each sustained for five minutes before the cuff pressure reading was taken: anterior flexion (O2), hyperextension (O3), left lateral flexion (O4), right lateral flexion (O5), left rotation (O6), and right rotation (O7).
10. At least five minutes elapsed between each successive position change, during which cuff pressure and the five physiological variables were measured and recorded before the next repositioning began.

Ethical Considerations

- Written permission to conduct the study was obtained from the Institutional Ethics Committee of DMCH, Ludhiana, Punjab.
- Written administrative permission was obtained from the Principal, College of Nursing, and the Head of the Department of Critical Care Medicine.
- The nature, purpose, and procedures of the study were explained to each patient's attendant/legally authorised representative in their own language, and written informed consent was obtained before enrolment.
- Anonymity of participants and confidentiality of information were maintained throughout, and care was taken to ensure that study procedures did not compromise participant safety or add to clinical risk.

Plan for Data Analysis

Data were coded and entered into Microsoft Excel and analysed using SPSS version 26. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarise socio-demographic, clinical, and cuff-pressure data. Inferential statistics -- the paired t-test, comparing each post-intervention position with the neutral baseline, and one-way repeated-measures ANOVA, testing the overall effect of position -- were used to test the study hypothesis at a 0.05 level of significance.

Plan for Writing References

References were prepared in accordance with the format recommended by the institutional research committee and the Vancouver style (International Committee of Medical Journal Editors guidelines, as first issued in 1993), consistent with convention for nursing and biomedical research reporting.

Results

Data were collected from 30 mechanically ventilated patients over the course of March 2022. Following Kerlinger's (1973) definition of analysis as the ordering, categorising, and summarising of data to answer a research question, collected data were coded, tabulated, and analysed descriptively and inferentially in two sections: Section I presents the socio-demographic and clinical profile of the sample, and Section II presents the principal findings relating to the effect of head position change on cuff pressure and on secondary physiological variables.

Socio-demographic and Clinical Profile

The sample (N = 30) had a mean age of 56.83 +/- 18.927 years. The largest age band was 61-80 years (12 patients, 40.0%), followed by 41-60 years (9, 30.0%), 21-40 years (5, 16.6%), and, equally, ≤20 years and ≥81 years (2 each, 6.7%). Twenty-one patients (70.0%) were male and nine (30.0%) were female. Habitat was evenly split between rural and urban residence (15 each, 50.0%). Regarding education, 13 patients (43.3%) had completed secondary schooling, 9 (30.0%) were graduates or above, 7 (23.3%) had primary education, and 1 (3.3%) was illiterate. Nineteen patients (63.3%) identified as Hindu and 11 (36.7%) as Sikh. Most patients were married (22, 73.4%), with unmarried and widowed/widowed patients equally represented (4 each, 13.3%). Family structure was evenly split between joint and nuclear households (15 each, 50.0%). Seventeen patients (56.7%) were vegetarian, 12 (40.0%) non-vegetarian, and 1 (3.3%) eggitarian. Twenty patients (66.7%) reported no substance use, while 10 (33.3%) reported a history of substance use. The great majority (27, 90.0%) were working prior to admission, and most fell into the lower-middle (18, 60.0%) or upper-middle (12, 40.0%) socio-economic bracket, with no patients in the uppermost or lowest strata.

With respect to the clinical profile, most patients (27, 90.0%) were admitted via the emergency department rather than the outpatient department (3, 10.0%). Twenty-two patients (73.3%) had at least one co-morbidity. Body mass index was most commonly in the normal range (13, 43.3%), followed by overweight (11, 36.7%), underweight (4, 13.3%), and obese (2, 6.7%). The majority were normothermic (26, 86.7%, 97.9-99.5 degF), with smaller proportions mildly febrile (3, 10.0%) or febrile (1, 3.3%, ≥101 degF). Hospitalisation duration was most often 1-5 days (16, 53.3%), and ICU stay was most often 1-5 days (19, 63.3%). Duration of intubation was most often 1-4 days (17, 56.7%). The commonest indication for intubation was altered conscious level (18, 60.0%), followed by other indications (8, 26.7%) and respiratory distress (4, 13.3%). Sedation depth, measured on the Richmond Agitation-Sedation Scale, was distributed between -3 (moderate sedation; 15, 50.0%), -4 (deep sedation; 14, 46.7%), and -5 (unarousable; 1, 3.3%), consistent with the inclusion criterion of RASS -3 or deeper.

All patients (30, 100.0%) were intubated with polyvinyl chloride tubes with polyvinyl chloride, barrel-shaped cuffs. Tube size was most often 8.0 mm internal diameter (19, 63.3%), followed by 7.5 mm (9, 30.1%), with 7.0 mm and 8.5 mm each accounting for one patient (3.3%). Tube depth at the lip line was most often 22 cm (19, 63.3%), followed by 23 cm (9, 30.0%) and 21 cm (2, 6.7%). Notably, baseline cuff pressure prior to protocol adjustment was already ≥30 cmH₂O in 21 patients (70.0%), between 20 and 30 cmH₂O in 8 (26.7%), and below 20 cmH₂O in only 1 (3.3%) -- a finding that itself underscores how easily cuff pressure drifts out of the safe range during routine care, before any experimental manoeuvre is applied. Tube position in the mouth was most often left-sided (21, 70.0%), followed by right-sided (7, 23.3%) and midline (2, 6.7%).

Ventilator mode was most often volume-controlled ventilation (12, 40.0%), followed by continuous positive airway pressure/pressure support (8, 26.7%), pressure-controlled ventilation (5, 16.7%), assist-control volume control (4, 13.3%), and synchronised intermittent mandatory ventilation (1, 3.3%). FiO₂ was most often 25-50% (17, 56.7%), PEEP was most often 5-8 cmH₂O (28, 93.4%), the inspiratory:expiratory ratio was most often 1:2 (15 of 22 applicable patients, 68.2%), and tidal volume was most often 450 mL (12 of 17 applicable patients, 70.6%). On arterial blood gas analysis, pH was below 7.35 in 12 patients (40.0%), within normal limits (7.35-7.45) in 10 (33.3%), and above 7.45 in 8 (26.7%); PaCO₂ was below 35 mmHg or within 35-45 mmHg in equal numbers (13 each, 43.3%), with the remainder (4, 13.3%) above 45 mmHg; PaO₂ was most often 101-200 mmHg (14, 46.7%); and HCO₃ was most often below 22 mEq/L (14, 46.7%).

Table 1. Frequency and percentage distribution of mechanically ventilated patients by socio-demographic profile (N = 30)

Socio-demographic variable	Category	f (%)
Age (years); Mean +/- SD = 56.83 +/- 18.927	≤20	2 (6.7)
	21-40	5 (16.6)
	41-60	9 (30.0)
	61-80	12 (40.0)
	≥81	2 (6.7)
Gender	Male	21 (70.0)
	Female	9 (30.0)
Habitat	Rural	15 (50.0)
	Urban	15 (50.0)
Educational status	Illiterate	1 (3.3)
	Primary	7 (23.3)
	Secondary	13 (43.4)
	Graduate and above	9 (30.0)
Religion	Sikh	11 (36.7)
	Hindu	19 (63.3)
Marital status	Married	22 (73.4)
	Unmarried	4 (13.3)
	Widow/widower	4 (13.3)
Family structure	Joint	15 (50.0)
	Nuclear	15 (50.0)
Dietary habits	Vegetarian	17 (56.7)

	Non-vegetarian	12 (40.0)
	Eggetarian	1 (3.3)
Substance use	Yes	10 (33.3)
	No	20 (66.7)
Occupation	Working	27 (90.0)
	Not working	3 (10.0)
Socio-economic status	Upper middle	12 (40.0)
	Lower middle	18 (60.0)

Table 2. Characteristics of the endotracheal tube and baseline cuff pressure (N = 30)

Variable	Category	f (%)
ETT material	Polyvinyl chloride	30 (100.0)
ETT cuff material	Polyvinyl chloride	30 (100.0)
ETT cuff shape	Barrel	30 (100.0)
ETT size (internal diameter)	7.0 mm	1 (3.3)
	7.5 mm	9 (30.1)
	8.0 mm	19 (63.3)
	8.5 mm	1 (3.3)
ETT depth at lip line	21 cm	2 (6.7)
	22 cm	19 (63.3)
	23 cm	9 (30.0)
Baseline (pre-protocol) cuff pressure	<20 cmH ₂ O	1 (3.3)
	20-30 cmH ₂ O	8 (26.7)
	>30 cmH ₂ O	21 (70.0)
ETT position in mouth	Left side	21 (70.0)
	Right side	7 (23.3)
	Midline	2 (6.7)

Effect of Head Position Change on Endotracheal Tube Cuff Pressure

Table 3 summarises the principal finding of the study. Mean cuff pressure in the neutral (pre-intervention) position was 25.23 +/- 1.278 cmH₂O, comfortably within the accepted safe range. Anterior flexion produced the largest rise, to 32.47 +/- 3.137 cmH₂O, a mean increase of over 7 cmH₂O that carried the

cuff decisively above the 30 cmH₂O ceiling ($t = 12.674$, $p = 0.000$). Left lateral flexion produced a smaller but still statistically significant rise, to 28.87 ± 4.883 cmH₂O ($t = 3.840$, $p = 0.001$), remaining within the upper part of the safe range on average but with a standard deviation wide enough that a meaningful proportion of individual patients likely exceeded 30 cmH₂O. Hyperextension (27.07 ± 6.319 cmH₂O, $p = 0.132$), right lateral flexion (25.27 ± 7.865 cmH₂O, $p = 0.981$), left rotation (23.87 ± 3.451 cmH₂O, $p = 0.067$), and right rotation (25.23 ± 6.285 cmH₂O, $p = 1.000$) did not differ significantly from the neutral baseline, though several of these positions showed considerably larger standard deviations than the baseline reading, indicating more inter-patient variability in direction and magnitude of change even where the mean effect was not significant. One-way ANOVA confirmed that head position had a highly significant overall effect on cuff pressure ($F = 9.709$, $p = 0.000$), and on this basis the null hypothesis of no effect was rejected.

Table 3. Comparison of endotracheal tube cuff pressure across head positions among mechanically ventilated patients (N = 30, df = 29)

Head position	Mean +/- SD (cmH ₂ O)	t (vs. neutral)	p-value	Significance
Neutral position (pre-intervention baseline)	25.23 +/- 1.278	--	--	--
Anterior flexion	32.47 +/- 3.137	12.674	0.000	Significant
Hyperextension	27.07 +/- 6.319	1.548	0.132	Not significant
Left lateral flexion	28.87 +/- 4.883	3.840	0.001	Significant
Right lateral flexion	25.27 +/- 7.865	0.024	0.981	Not significant
Left rotation	23.87 +/- 3.451	1.907	0.067	Not significant
Right rotation	25.23 +/- 6.285	0.000	1.000	Not significant

One-way ANOVA across all seven positions: $F = 9.709$, $p = 0.000$ (significant). Significance level: $p < 0.05$.

Effect of Head Position Change on Physiological Variables

Table 4 presents the corresponding findings for the five secondary physiological variables. Heart rate showed a small, statistically significant fall specifically during hyperextension (98.90 ± 22.435 to 95.47 ± 20.949 beats/min, $p = 0.009$), but the overall ANOVA across positions was non-significant ($F = 0.083$, $p = 0.998$), suggesting this single comparison reflects normal physiological fluctuation rather than a true positional effect. Minute ventilation fell significantly during left rotation (9.80 ± 2.852 to 9.23 ± 2.736 L/min, $p = 0.010$) and right rotation (9.41 ± 2.786 L/min, $p = 0.011$), again without a significant overall ANOVA effect ($F = 0.150$, $p = 0.989$). Respiratory rate, oxygen saturation, and peak inspiratory pressure showed no significant change in any individual position or overall. Taken together, these findings indicate that while head position change produced a clear and clinically important effect on cuff pressure, it did not produce a correspondingly consistent or clinically meaningful disturbance in ventilation or haemodynamic status during the brief, five-minute exposure windows used in this protocol.

Table 4. Effect of head position change on selected physiological variables among mechanically ventilated patients (N = 30, df = 29)

Physiological variable	Position	Mean +/- SD	t (vs. neutral)	p-value
Heart rate (beats/min); baseline 98.90 +/- 22.435	Anterior flexion	96.57 +/- 22.499	1.986	0.057 NS
	Hyperextension	95.47 +/- 20.949	2.796	0.009*
	Left flexion	98.03 +/- 20.619	0.508	0.615 NS
	Right flexion	97.90 +/- 20.842	0.761	0.453 NS
	Left rotation	97.13 +/- 20.594	1.333	0.193 NS
	Right rotation	96.90 +/- 21.095	1.444	0.160 NS
Respiratory rate (breaths/min); baseline 17.47 +/- 3.998	Anterior flexion	18.07 +/- 5.291	0.858	0.398 NS
	Hyperextension	17.60 +/- 3.802	0.812	0.423 NS
	Left flexion	17.83 +/- 3.824	1.613	0.118 NS
	Right flexion	17.53 +/- 3.919	0.328	0.745 NS
	Left rotation	17.67 +/- 3.790	1.361	0.184 NS
	Right rotation	17.57 +/- 3.839	0.593	0.557 NS
Oxygen saturation (%); baseline 98.77 +/- 1.716	Anterior flexion	98.70 +/- 1.643	0.812	0.423 NS
	Hyperextension	98.90 +/- 1.494	1.682	0.103 NS
	Left flexion	98.77 +/- 1.633	0.000	1.000 NS
	Right flexion	98.77 +/- 1.478	0.000	1.000 NS
	Left rotation	98.80 +/- 1.648	0.571	0.573 NS
	Right rotation	98.97 +/- 1.450	1.989	0.056 NS
Minute ventilation (L/min); baseline 9.80 +/- 2.852	Anterior flexion	9.53 +/- 2.826	1.564	0.129 NS
	Hyperextension	9.39 +/- 2.676	2.041	0.051 NS
	Left flexion	9.67 +/- 2.705	0.471	0.641 NS
	Right flexion	9.63 +/- 2.692	0.696	0.492 NS
	Left rotation	9.23 +/- 2.736	2.743	0.010*
	Right rotation	9.41 +/- 2.786	2.716	0.011*
Peak inspiratory pressure (cmH ₂ O); baseline 21.00 +/- 6.818	Anterior flexion	21.33 +/- 7.743	0.881	0.386 NS
	Hyperextension	20.83 +/- 6.823	0.614	0.544 NS
	Left flexion	20.47 +/- 6.786	1.332	0.193 NS

	Right flexion	20.20 +/- 7.867	1.179	0.248 NS
	Left rotation	21.07 +/- 7.381	0.205	0.839 NS
	Right rotation	20.77 +/- 6.986	0.793	0.434 NS

* $p < 0.05$ (statistically significant); NS = not significant. One-way ANOVA across positions was non-significant for all five physiological variables (heart rate $F = 0.083$, $p = 0.998$; respiratory rate $F = 0.077$, $p = 0.998$; oxygen saturation $F = 0.101$, $p = 0.996$; minute ventilation $F = 0.150$, $p = 0.989$; peak inspiratory pressure $F = 0.083$, $p = 0.998$), indicating that head position change did not produce an overall, clinically meaningful disturbance in ventilation or haemodynamics.

Discussion

This study set out to determine whether, and to what extent, changing head position alters ETT cuff pressure in mechanically ventilated patients cared for in an Indian tertiary care ICU. The principal finding -- that anterior flexion produces a large, highly significant rise in cuff pressure, that left lateral flexion produces a smaller but still significant rise, and that hyperextension and rotation produce no significant mean change -- both confirms and refines the pattern reported in the international literature.

The socio-demographic and clinical profile of the sample is consistent with a typical Indian tertiary care ICU case-mix: a predominantly older, male population (mean age 56.83 years; 70.0% male), commonly admitted as an emergency (90.0%), with a high burden of co-morbidity (73.3%) and altered consciousness as the leading indication for intubation (60.0%). This profile mirrors, in broad terms, the case-mix reported in comparable positional studies from Iranian and other Asian ICUs (Nazari et al., 2020; Okgun Alcan et al., 2017), lending some support to the generalisability of the physiological findings across these settings, even though direct comparison of demographic figures across studies conducted in different health systems must be made cautiously.

The finding that anterior flexion raised mean cuff pressure by over seven cmH₂O, carrying it decisively above the safe ceiling, closely parallels the central finding of Nazari et al. (2020), whose quasi-experimental study using an almost identical six-position protocol also identified anterior flexion (together with left rotation) as the position producing the greatest pressure rise, with a substantial proportion of patients exceeding 30 cmH₂O. The present study's finding for left lateral flexion, a smaller but still statistically significant rise, is consistent with the flexion-dominant pattern reported by Kako et al. (2014) in a paediatric population, where flexion of the head and neck was the manoeuvre most reliably associated with an intracuff pressure increase, and by Inoue et al. (1998), whose early mechanistic work attributed flexion-induced pressure rises to caudal migration of the tube tip relative to a shortened, curved trachea rather than to any change in the volume of air within the cuff itself. The absence of a significant mean change during hyperextension in the present study contrasts somewhat with Kara et al. (2020), who found that neck extension alone (using an under-shoulder pillow) produced a significant rise from the neutral baseline; this discrepancy may reflect differences in the degree of extension achieved, tube fixation technique, or cuff design between the two study populations, and illustrates why locally generated evidence, of the kind produced here, remains necessary even where broadly similar findings have already been published elsewhere.

The magnitude of overinflation observed during anterior flexion in this study, a rise to a mean of 32.47 cmH₂O from a baseline of 25.23 cmH₂O, is broadly comparable to the scale of change reported by Okgun Alcan et al. (2017), who found mean cuff pressure rising from 25 to 32.59 cmH₂O across sixteen

positions in a mixed ICU sample, and by Lizy et al. (2014), who documented a significant deviation in cuff pressure with every one of sixteen tested positions and reported that 40.6% of measurements exceeded the upper safe limit. Both of these studies, like the present one, emphasise that overinflation during repositioning is common, often clinically silent, and therefore easy to miss unless cuff pressure is actively re-checked after every substantial change in head or body position rather than at fixed time intervals alone.

A striking and clinically relevant secondary finding was that baseline (pre-protocol) cuff pressure was already ≥ 30 cmH₂O in 70.0% of patients before any experimental manoeuvre was applied. This finding echoes Rosero et al. (2018), who found 89% of cuffs overinflated immediately after intubation in a surgical population, and reinforces the broader concern, raised by several of the reviewed studies (Asai et al., 2014; Sole et al., 2003, 2009), that unmonitored cuffs drift out of the safe range as a matter of routine, independent of any deliberate repositioning. In the context of the present study, this means that many patients entered the experimental protocol already at, or above, the threshold associated with impaired tracheal mucosal perfusion, and that the further rise recorded during anterior flexion represents an addition to, rather than the sole source of, cumulative airway risk.

That the five secondary physiological variables -- heart rate, respiratory rate, oxygen saturation, minute ventilation, and peak inspiratory pressure -- showed no consistent or clinically meaningful change across positions is a reassuring finding from a patient-safety perspective: it suggests that the positioning manoeuvres used in this protocol, held for five minutes each, were physiologically well tolerated by adequately sedated patients selected according to the study's exclusion criteria. This should not, however, be read as evidence that the observed rise in cuff pressure during anterior flexion is clinically inconsequential. The complications associated with sustained cuff overinflation (tracheal mucosal ischaemia, ulceration, and, over a longer time course, stenosis or fistula) develop gradually and are not expected to manifest as an acute change in heart rate or oxygen saturation over a single five-minute exposure (El-Orbany & Salem, 2013; Guyton et al., 1991). The two variables together therefore support complementary, rather than contradictory, conclusions: the manoeuvre itself is haemodynamically safe to perform, but its downstream effect on cuff pressure is not incidental and warrants a corresponding change in monitoring practice.

From a mechanistic standpoint, the pattern of findings across this and the comparator studies is coherent with a physical, rather than purely physiological, explanation. Flexion of the neck reduces the distance between the larynx and the carina, effectively drawing a fixed-length endotracheal tube deeper relative to the trachea and compressing the cuff against a segment of airway with a smaller effective cross-sectional area, both of which raise the pressure recorded at the pilot balloon (Kako et al., 2014; Inoue et al., 1998). Extension has the converse effect, lengthening the exposed trachea and tending to withdraw the tube, which is consistent with the small, non-significant fall in mean cuff pressure observed during hyperextension in this study and with the pressure loss and air leak reported during extension by Inoue et al. (1998). Rotation and lateral flexion, which act through torsion and asymmetric wall contact rather than simple axial displacement, produced more variable, generally non-significant changes in the present sample, mirroring the mixed findings reported for these positions across the wider literature (Lizy et al., 2014; Choi et al., 2017).

Limitations

- Data collection took place over a relatively short period, which limits the extent to which findings can be generalised across seasons, staffing patterns, or patient case-mix variation over time.
- The study was conducted exclusively within the critical care units of a single tertiary care institution, which may limit generalisability to other hospital settings, particularly those using different tube brands, fixation techniques, or nursing staffing ratios.
- The sample size (N = 30) was modest, limiting statistical power for detecting smaller effects, particularly in the secondary physiological variables, and constraining subgroup analysis (for example, by tube size, sedation depth, or diagnosis).
- The one-group pre-test-post-test design, while appropriate for a first exploratory study of this kind, does not include a concurrent comparison group and cannot fully exclude the possibility that other, uncontrolled time-related factors contributed to the observed changes.

Conclusion

This study demonstrates that head position exerts a statistically significant and, in the case of anterior flexion, clinically important effect on endotracheal tube cuff pressure in mechanically ventilated patients. Anterior flexion produced the largest rise, carrying mean cuff pressure from a safe baseline of 25.23 cmH₂O to an unsafe 32.47 cmH₂O, and left lateral flexion produced a smaller but still significant rise; hyperextension, right lateral flexion, left rotation, and right rotation did not differ significantly from baseline on average, though individual variability was evident across all positions. The overall effect of position on cuff pressure was highly significant ($F = 9.709$, $p = 0.000$), and the null hypothesis was accordingly rejected. In contrast, none of the five secondary physiological variables assessed showed a consistent, clinically meaningful change across positions, indicating that the repositioning protocol was physiologically well tolerated even as it produced a materially important change in airway cuff pressure.

These findings support the incorporation of position-triggered cuff pressure verification into routine nursing practice, particularly whenever a mechanically ventilated patient's head is flexed forward for any clinical reason -- for example, during oral care, feeding, tube fixation checks, or repositioning for comfort or pressure-area care.

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