

## Does the Endotracheal Tube Cuff Pressure Increases with Transesophageal Probe Insertion?

### Abstract

**Context:** The cuff pressure (CP) of the endotracheal tube (ETT) exceeding 30 cm of H<sub>2</sub>O results in reduced perfusion of lateral mucosa of trachea leading to complications. As the posterior tracheal wall is in contact with the esophagus, there is a possibility that the insertion of transesophageal echo (TEE) probe may compress the tracheal wall and increase CP. **Aims:** This study was aimed to assess the impact of TEE probe insertion on CP in adults undergoing cardiac surgery. **Settings and Design:** Prospective observational study of 65 patients at tertiary care level hospital. **Subjects and Methods:** After balanced general anesthesia, patients were intubated with high volume low-pressure ET.TEE probe was then inserted with gentle jaw thrust. CP was measured by standard invasive pressure monitoring device at four points: T1 at baseline before TEE probe insertion; T2 maximum CP noted at TEE probe insertion; T3 at 5 min post TEE probe insertion; and T4 at post-TEE exam. **Statistical Analysis Used:** CP was compared between pairs of time points (T1 vs. T2; T1 vs. T3; and T1 vs. T4) using Mann-Whitney U test. Factors predicting CP >30 cm of H<sub>2</sub>O at T4 were assessed by backward stepwise regression. **Results:** CP (mean ± S.D.) at T1, T2, T3, and T4 was 22 ± 3, 38 ± 10, 30 ± 6, and 30 ± 7, respectively. CP increased significantly from T1 to T2 ( $P < 0.001$ ), T1 to T3 ( $P < 0.001$ ), and T1 to T4 ( $P < 0.001$ ). There were 26 patients (40%) with CP >30 cm of H<sub>2</sub>O at end of TEE exam (T4). On multivariate analysis baseline, CP (T1) >20 cm of H<sub>2</sub>O was significantly associated with CP >30 cm of H<sub>2</sub>O at end of TEE exam with Odd's Ratio (OR) of 8.5 (1.76–41.06,  $P = 0.008$ ). **Conclusions:** To conclude, the CP increases significantly with TEE probe insertion in 40% of patients exceeding a safe limit of 30 cm of H<sub>2</sub>O. The monitoring and optimization of CP is advisable.

**Keywords:** Cuff pressure monitoring, endotracheal cuff pressure, TEE probe insertion

### Introduction

Inflation of endotracheal tube (ETT) cuff is common with cuff pressure (CP) exceeding the safe limit of 30 cm of H<sub>2</sub>O in about one-third patients.<sup>[1]</sup> Higher CP affects blood flow supply to the tracheal mucosa, resulting in tracheal mucosal ischemia, ulceration, necrosis, tracheo-esophageal fistula, or even tracheal rupture.<sup>[2-5]</sup> The assessment of CP by digital palpation remains the most prevalent method in contemporary clinical practice.<sup>[6]</sup> Unfortunately, regardless of seniority, clinicians are not able to reliably identify dangerously high CPs by pilot balloon palpation with any greater accuracy than pure chance.<sup>[7]</sup> A recent meta-analysis found evidence that adjustment of CP guided by objective measurement as compared with subjective measurement or observation of the pressure value

alone has benefit in preventing adverse effects such as cough, sore throat, lesions of the trachea, and incidences of silent aspiration.<sup>[8]</sup> The transducer of the invasive pressure monitoring device can be used reliably to measure the CP at the time of inflation of ETT cuff and continuously thereafter.<sup>[9-12]</sup>

There can be significant variations in the CP during prolonged surgical procedures.<sup>[13]</sup> In patients, undergoing cardiac surgery, CP can be affected by hypothermia induced by cardiopulmonary bypass (CPB) in both adult and pediatric patients.<sup>[14,15]</sup> The perioperative use of transesophageal echocardiography has increased significantly in cardiac surgery. As the posterior membranous tracheal wall is in contact with the esophagus, there is a possibility that the transesophageal echo (TEE) probe may compress the tracheal wall and increase CP. There is limited data on this topic<sup>[16-18]</sup> with studies

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enrolling only small number of patients, measuring CP only once after TEE insertion,<sup>[16]</sup> different tube designs (single lumen vs. double lumen)<sup>[17]</sup> or pediatric patient population, which may have different distensibility of trachea/esophagus than adults.<sup>[18]</sup>

The authors tested the hypothesis that TEE probe insertion significantly increases CP in adults undergoing cardiac surgery.

## Subjects and Methods

This was a prospective observational study at a tertiary care level hospital. The Institutional Review Board approved the study. All patients undergoing cardiac surgery are monitored with TEE in authors' institute unless contraindicated; hence, additional consent for the study was waived-off. The study was conducted in consecutive adult patients above 18 years of age undergoing cardiac surgery and intraoperative TEE during October to December 2018. Patients with pre-existing tracheal or esophageal pathology were excluded.

There was no premedication administered. Standard monitoring such as electrocardiography and pulse oximetry were applied. Femoral artery and central venous catheters through right internal jugular vein were inserted under standard aseptic precautions. The anesthetic induction was done with midazolam, fentanyl, and etomidate. In all patients, neuromuscular blockade was provided by vecuronium. After anesthetic induction, an appropriate-sized (7 or 7.5 for female and 8 or 8.5 for male) cuffed Portex® ETT (Smith Medical ETT, Kent, UK) was used to secure the airway. After ensuring proper placement, it was confirmed with EtCO<sub>2</sub> tracing and auscultation of the air entry bilaterally. The cuff of the ETT was slowly inflated using the air leak technique by putting the stethoscope on the suprasternal notch to seal the airway. Mechanical ventilation was started with volume-controlled mode with the following settings: tidal volume 8 to 10 ml/kg of predicted body weight; respiratory rate adjusted to maintain an EtCO<sub>2</sub> of 25–30; inspiratory/expiratory ratio 1: 2; and inspiratory oxygen fraction 0.6 with an air-oxygen mixture with sevoflurane. Positive end-expiratory pressure was not applied. We did not use nitrous oxide. After the ETT cuff was inflated, the CP was monitored continuously using the transducer from a standard invasive pressure-monitoring device (Edwards Life Sciences™ Monitoring Kit, Irvine, CA, USA). This transducer is routinely used at authors' institute to measure arterial or central venous pressure. This transducer was attached to the pilot balloon of the ETT to obtain CP trace on monitor as shown in Figure 1. The CP measurements were obtained after zeroing the transducer to air. Attention was paid to ensure that the transducer was attached tightly to the pilot balloon of the ETT to avoid the potential for air leak.

After that, TEE probe (Siemens Acuson X300) was inserted after adequate lubrication and a brief jaw thrust maneuver.



Figure 1: Cuff pressure trace and number in a sample patient (note CP = 17)

Experienced cardiac anesthesiologist (>5 years) inserted the probe and managed all cases. Bite guard was used after TEE probe placement. If blind insertion of the TOE probe was not possible after two attempts, the probe was then inserted using direct laryngoscopy, or the procedure was abandoned if significant resistance was encountered. These patients were also excluded from the study. Any TEE-associated complications (e.g., dental injury, upper gastrointestinal bleeding, and esophageal/gastric injury) were noted.

The CP was recorded at four points of time - before the insertion of the TEE as a baseline (T1); maximum pressure during TEE probe insertion (T2); 5 min after TEE probe insertion (T3); and after the TEE exam (T4). If the pressure was found to be persistently >30 cm of H<sub>2</sub>O at T4, this was adjusted back to 25–30 cm of H<sub>2</sub>O. When the intra CP was >30 cm of H<sub>2</sub>O, air was removed from the cuff until the intra CP was <30 cm of H<sub>2</sub>O. Alternatively, air was added to the cuff, if there was an audible air leak or if there was inadequate ventilation because of loss of tracheal seal. On the basis of previous study,<sup>[16]</sup> which reported that CP increased by  $8.5 \pm 6.4$  cm of H<sub>2</sub>O after TEE probe insertion, a sample size of at least 18 patients was needed to have 90% power for detecting an increase (approximately, 5 cm of H<sub>2</sub>O) at a 95% confidence level.

The primary aim of the study was to assess the impact of TEE probe insertion on CP in adults undergoing cardiac surgery. The secondary aim of the study was to assess factors associated with CP more than safe limit i.e. 30 cm of H<sub>2</sub>O at the end of TEE exam (T4). All pressure measurements were recorded in mm of Hg and subsequently were converted to cm of H<sub>2</sub>O using the formula: 1 mm of Hg = 1.36 cm of H<sub>2</sub>O. CP was compared between pairs of time points (T1 vs. T2; T1 vs. T3; and T1 vs. T4) using Mann-Whitney U test. Factors predicting CP >30 cm of H<sub>2</sub>O at T4 were assessed by backward stepwise regression. A *P* value <0.05 was considered as significant. The Statistical Package for the Social Sciences (SPSS) version 15.0 (Chicago, IL, USA) was used to perform data analysis.

## Results

Sixty- seven patients were recruited in this study. Two patients were excluded as they required use of laryngoscope and deflation of ETT cuff after initial failed attempt of blind probe insertion. The final study included 65 patients. The basic demographic characteristics are as shown in Table 1. There were 20 (30.7%) female patients. There were no major TEE-related complications (e.g., dental injury, upper gastrointestinal bleeding, and esophageal/gastric injury) in any of the patients during the hospital stay.

CP (mean ± S.D.) at T1, T2, T3, and T4 was 22 ± 3, 38 ± 10, 30 ± 6, and 30 ± 7, respectively [Figure 2]. CP increased significantly from T1 to T2 ( $P < 0.001$ ), T1 to T3 ( $P < 0.001$ ), and T1 to T4 ( $P < 0.001$ ).

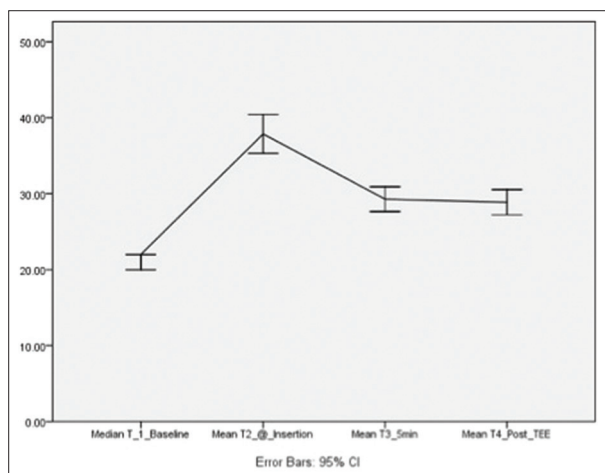
There were 26 patients (40%) with CP >30 cm of H<sub>2</sub>O at end of TEE exam (T4). On multivariate analysis baseline, CP (T1)>20 cm of H<sub>2</sub>O was significantly associated with CP >30 cm of H<sub>2</sub>O at end of TEE exam with Odd's ratio (OR) of 8.5 (1.76–41.06,  $P = 0.008$ ). There were no other patient demographic factors predicted with CP >30 cm of H<sub>2</sub>O at end of TEE exam.

## Discussion

The main findings of the study are CP increased

**Table 1: Basic demographic characteristics of 65 patients presented as mean (SD)**

Patient characteristics	Values
Age (years)	55 (7)
Female (%)	20 (30.7%)
Weight (Kg)	60.4 (6)
Height (cm)	161 (9)
Body surface area (m <sup>2</sup> )	1.65 (0.36)
Surgery (%)	Coronary Artery Bypass Grafting=49 (75%) Valve replacement=13 (20%) Atrial Septal Defect closure=3 (5%)



**Figure 2: Change in Cuff pressure over 4 points of measurement**

significantly with TEE probe insertion; 40% patients had high (>30 cm of H<sub>2</sub>O) CP even at the end of the TEE exam; patients baseline CP >20 cm of H<sub>2</sub>O had 8-fold higher probability of CP >30 cm of H<sub>2</sub>O at end of TEE exam.

TEE has evolved as a major monitoring and diagnostic tool during cardiac surgery in the last few decades. According to a recent survey,<sup>[19]</sup> new findings are considered in decision-making, and surgical plan is altered in many cases from TEE findings. TEE is considered as a relatively safe procedure, still overall incidence of TEE complications after cardiac surgery can be as much as 1.4% patients including dysphagia, vocal cord and laryngeal injury, dysphonia, esophageal, and gastric lacerations.<sup>[20]</sup> The esophagus lies directly posterior to the trachea. Owing to this anatomic relationship, insertion of a TEE probe may compress the adjacent tracheal wall and increase tracheal CP. Excessive CP can reduce tracheal mucosal blood flow, resulting in tracheal morbidity. TEE probe remains *in situ* for many hours. The higher CP may result in lower tracheal mucosal perfusion particularly during periods of hemodynamic instability. This complication is not well reported in the literature compared to other complications of TEE.

In one of the initial studies, Tan *et al.*<sup>[16]</sup> measured CP with manometer in 28 patients undergoing cardiac surgery. The CP was monitored 1 min after TEE probe insertion after initial adjustment of CP to 25–30 cm of H<sub>2</sub>O. After probe insertion, the mean CP increased from 27.7 to 36.2 cm of H<sub>2</sub>O ( $P < 0.001$ ) and was >35 cm of H<sub>2</sub>O in 45% of patients. Important limitations of the study include a small number of patients enrolled and measurement of CP only for 1 min. In present study, we measured CP till the end of TEE exam and found that in 40% of patients, CP remained above the safe limit of 30 cm of H<sub>2</sub>O. In another study by Kim *et al.*<sup>[17]</sup> enrolled 44 patients divided in two groups, 22 each in single and double lumen tube group. Invasive pressure transducer measured the CP continuously for 5 min, and they demonstrated that CP reached a steady state in 3 min. Insertion of the TEE probe increased CP in both single and double lumen tube, but it was greater in double lumen tube group. The authors recommended that frequent measurement of CP should be employed with the use of TEE probe. We also measured CP with a routine invasive pressure transducer. The advantage of this method of measurement is, it has been validated against manometer measurement,<sup>[9-12]</sup> it is readily available in operation rooms, and importantly, it can give real-time values, which can mandate immediate action to keep CP below the safe limit of 30 cm of H<sub>2</sub>O.

In contrast to above studies of adult patients, another study<sup>[18]</sup> of 80 pediatric patients undergoing cardiac surgery for congenital heart diseases with cuffed ET and TEE monitoring demonstrated that increase in CP is only



transient during TEE probe placement and it normalizes by the time probe is advanced in the stomach. This was evident across various age groups. The authors attributed this difference from previous two studies in the adult population to type of ETT, type of cuff, depth of TEE probe insertion in variability in distensibility of trachea/esophagus in pediatric population compared to adults. In our study, on backward regression analysis, none of the patient demographic factors were associated with higher CP at end of TEE exam, but baseline CP more than 20 cm of H<sub>2</sub>O was significantly associated [OR of 8.5 (1.76–41.06,  $P = 0.008$ ) with high CP (>30 cm of H<sub>2</sub>O)] at end of TEE exam.

A recent meta-analysis<sup>[8]</sup> (9 studies) examined whether adjustment of CP guided by objective measurement, compared with subjective measurement or observation of the pressure value alone, was able to prevent patient-related adverse effects and maintain accurate CPs. The authors demonstrated that adjustment of CP has benefit in preventing adverse effects such as cough (odds ratio [OR] 0.42,  $P = 0.007$ ), hoarseness at 24 h (OR 0.49,  $P < 0.002$ ), sore throat (OR 0.73,  $P < 0.03$ ), lesions of the trachea and incidences of silent aspiration ( $P = 0.001$ ). Subjective measurement to guide adjustment or observation of the pressure value alone may lead to patient-related adverse effects and inaccuracies. The authors recommended that an objective form of measurement be used. In a multicenter study, Liu *et al.*<sup>[21]</sup> observed that CP estimated by palpation with personal experience is often much higher than measured or what may be optimal. Control of CP resulted in a lower incidence of post-procedure respiratory complications even in short duration procedures. It will be important to demonstrate in future studies whether higher CP is also associated with complications with TEE probe insertion and optimizing CP can reduce TEE related complications. In a randomized clinical trial, Rubes *et al.*<sup>[22]</sup> demonstrated that active CP management in patients undergoing deep hypothermic circulatory arrest resulted in a lower incidence of silent aspiration and prolonged postoperative ventilation.

Unfortunately, regardless of seniority, clinicians are not able to reliably identify dangerously high CPs by pilot balloon palpation with any greater accuracy than pure chance.<sup>[7]</sup> However still, in a recent, Canadian survey pilot balloon palpation was the most common technique used to estimate CP.<sup>[6]</sup> Common reported barriers to cuff manometer use were the lack of availability, perceived lack of clinical evidence, and “laziness.” Hence, the use of invasive pressure transducer can be a simple solution. We also recommend monitoring CP continuously when the TEE probe is used in cardiac surgical patients.

There are important limitations of the present study, the investigator recording the data was not blinded to the TEE probe insertion, and the CP indirectly reflects tracheal mucosal pressure.

To conclude, the CP increases significantly with TEE probe insertion in 40% patients exceeding the safe limit of 30 cm of H<sub>2</sub>O. The monitoring and optimization of CP is advisable.

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### Conflicts of interest

There are no conflicts of interest.

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