original article

Effect of different patient positions on endotracheal tube cuff pressure in patients undergoing urological procedures: a prospective study

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BACKGROUND: The endotracheal tube (ETT) contains a cuff that is placed in the trachea to prevent gas leakage and aspiration of secretions and gastric contents. However, patient positioning after intubation may cause ETT displacement and changes in cuff pressure.
OBJECTIVES: Evaluate the effect of different patient positions on ETT cuff pressure in patients undergoing urological procedures in supine, prone, lateral flank, and lithotomy positions.
DESIGN: Prospective and observational study
SETTING: A university hospital in Turkey
PATIENTS AND METHODS: Patients who underwent surgeries under general anesthesia in different patient positions were involved. After intubation (T0), the cuff pressure was checked with a manometer and adjusted to 25 cmH_2O and continuously monitored. The cuff pressure was checked before (T1) and after achieving the final position (T2) and then at 5, (T3), 10, (T4), 15 minutes (T5) of the position, at the end of the procedure (T6) and before extubation (T7). At postoperative 2nd and 12th hours, the patients were interviewed for sore throat, hoarseness, and cough.
MAIN OUTCOME MEASURES: The effect of different patient positions on the ETT cuff pressure.
SAMPLE SİZE: 200 patients
RESULTS: The cuff pressure increased significantly at T2 in the lithotomy, lateral flank, and prone groups (P<.001 each). The highest increase in cuff pressure occurred in the prone group (34.3 [7.5] cmH_2O). Over time, the cuff pressure decreased in all groups during surgery. Postoperative complications at the 2nd postoperative hour were similar in all groups; however, the mean cuff pressure was significantly higher in the patients with postoperative sore throat or cough (sore throat: P=.003; cough: P=.047).
CONCLUSION: ETT cuff pressures are affected by different patient positioning; therefore, regular recording and adjustment of cuff pressure are necessary for patient safety.
LIMITATION: We used ETT of a single manufacturer. Therefore, our findings may not be applicable to other types of ETT.
CONFLICT OF INTEREST: None.

Endotracheal intubation is a standard procedure undertaken to maintain an open airway and provide effective ventilation during anesthesia practice. During intubation, a balloon is present in the endotracheal tube (ETT) to prevent air leakage and avoid aspiration of secretions and gastric contents into the lungs.[1] Therefore, optimal cuff pressure and placement are important to ensure patient safety during operation. Ideally, the cuff must be kept within the normal pressure range (20-30 cmH_2O) for adequate mechanical ventilation. Insufficient balloon inflation or leakage of the endotracheal tube cuff can cause aspiration and related complications as well inaccurate tidal volume and ventilation.[2] While excessive inflation can cause complications ranging from postoperative pharyngeal discomfort, tracheal mucosal damage, tracheal stenosis, and tracheal rupture depending on the increase in cuff pressure.[3,4] Various factors, such as inflation volume, the relationship between the cuff and tracheal diameters, tracheal and cuff compliance, intrathoracic pressure, and neuromuscular blockage level affect cuff pressure.[5]

During surgical procedures, different patient positions are used according to the area being operated while accounting for the patient's ability to physically and structurally withstand the procedure and ensuring appropriate surgical access to the anatomical targets. The supine position (neutral position) is the most commonly used position in surgery and is standard for anesthetic induction. The patient lies on their back, facing upward. It is typically characterized by maintaining the body in a balanced state, where each joint is positioned in its natural alignment, without excessive flexion, extension, or rotation. The lithotomy position (while the patient is in a supine position, the arms are placed at less than 900 of abduction on the torso or arm boards, with the hips flexed at 80-1000 and the knees at 80-900. Both legs are elevated together and abducted 30-450 from the midline to allow the surgeon access to the perineum) is frequently used in gynecological, urological and rectal surgeries. Patient position after intubation may cause displacement of the ETT, leading to changes in the cuff pressure.[5-7] To the best of our knowledge, only a few studies have discussed the effect of ETT cuff pressure on different patient positions in surgeries and also investigating the effects of all positions on the cuff pressure in one study.[5,9-11]

In this study, we used a prospective-observational study design to evaluate the effect of different patient positions (lateral flank, prone, lithotomy, and supine) on the cuff pressure in urological surgeries. A secondary aim was to investigate the effect of changes in cuff pressure after position changes, operation and anesthesia time on postoperative throat pain, cough, and hoarseness.

PATIENTS AND METHODS

The protocol of the study was approved by the ethics committee of Ege University (Ethical Committee No.16-10/13,09.12.2016) and written informed consent was obtained from patients who were eligible for the study. We included 200 patients (aged 18-75 years; American Society of Anesthesiologists physical status I–II) who were planned for elective urological surgery to be performed in either supine, prone, lateral flank, or lithotomy position. Patients undergoing an emergency operation, having a history of chronic lung disease, upper and/or lower respiratory tract infection within 2 weeks preoperatively, who are morbidly obese were excluded.

In urological surgery, various operations are performed using different patient positions. The patients were divided into four groups based on the aforementioned surgical positions. The study was designed to include 50 patients in each group. It is noted that there were demographic differences among the groups based on the type of surgery performed (such as, percutaneous nephrolithotomy in the prone position and radical nephrectomy in the lateral decubitus position etc). In the operating room, routine monitoring using non-invasive arterial blood pressure, electrocardiogram, and pulse oximetry was conducted. After preoxygenation, 10 μg/kg atropine, 1 mg/kg lidocaine, 2-3 mg/kg propofol, 1-3 μg/kg fentanyl, and 0.6 mg/kg rocuronium bromide were administered intravenously. After adequate mask ventilation, all patients were intubated orotracheally (tube internal diameter: for women: 7-7.5 mm; for men: 8-8.5 mm). Ventilation in both lungs was confirmed by auscultation, and ETT position was determined after observing the end-tidal CO_2 ($ETCO_2$) waveform on capnograph. High-volume, low-pressure ETTs were used for intubation.

After intubation, the ETT cuff was inflated with air through an injector of 5-10 mL using standard methods. Cuff pressure following intubation (T0) was recorded in a neutral head position using an analog cuff manometer (VBM Medizintechnik®, GmbH, Germany). Immediately thereafter, cuff pressure was adjusted to 25 cmH_2O; the manometer continuously monitored the cuff pressure without separating it from the pilot balloon of the ETT. The patient was placed on volume-controlled mechanical ventilatory support (tidal volume=6-8 mL/kg [the tidal volume was calculated based on the patients' predicted body weight]; respiratory rate=12-16/min; $ETCO_2$=35-40 mmHg). For anesthesia maintenance, a mixture of 50% O_2 and air was used, along with sevoflurane (Sevorane Liquid 250 ml®, Abbott, UK) at 2% MAC and remifentanil infusion.

Next, cuff pressure was recorded before and after placing the patient in the required position for the surgery (T1 and T2, respectively); special attention was paid to keeping the head in a neutral position relative to the body. To prevent the effect of airway pressure on the manometer during cuff pressure measurement, the value seen at the end of expiration was recorded. Subsequently, values at 5th min (T3), 10th min (T4), 15th min (T5) intraoperatively were recorded. Finally, cuff pressure values were recorded after completing the surgical procedure (T6) and before extubation (T7); at this time, patients were placed in supine position for waking up. During the operation, cuff pressure was continuously monitored using an analog cuff manometer; however, values measured at specific time points at the end expiration were recorded. Patients were interviewed to determine if they had any complaints of sore throat, hoarseness, or cough at 2 h and 12 h postoperatively.

Statistical analysis and sample size

A previous study[10] described that the mean (standard deviation) ETT cuff pressure increases by 6.5 (3.9) cmH_2O after a positional change from supine to lateral decubitus position. Assuming a 50% reduction in the mean difference of cuff pressure (3.25 cmH_2O) (α=0.05; β=0.20), a sample size of 23 patients in each group was calculated. We included 50 patients per group.

Data were analyzed using SPSS for Windows (version 21.0). Demographic data were described as means and SDs within ranges. Between-group comparisons were analyzed using t-test. Comparison of different perioperative parameters at different time points was performed using one-way analysis of variance, followed by post-hoc testing; P<.05 was considered statistically significant.

RESULTS

All groups were comparable in terms of gender and BMI; however, the mean age of patients in the supine group was significantly lower compared to lateral flank and lithotomy groups (P<.05) (**Table 1**). The durations of anesthesia and surgery were significantly shorter in supine and lithotomy groups than in the other groups (P<.05); but without significant differences between prone and lateral flank groups.

Figure 1 presents the cuff pressure values at all measurement time points. There were no significant differences in the preposition (T1) cuff pressure between groups. No significant differences were observed between the mean cuff pressure values at T1 and T2 in the supine group. The T3 value was significantly higher than the T1 value (P<.05); the mean cuff pressure at the end of the surgical procedure (T6) was significantly lower than the T2, T3, T4, and T5 values (P<.05).

In the prone group, the mean cuff pressure measured at T2 was significantly higher than that at T1 (P<.001); notably, the mean cuff pressure at T2 was the highest for this group and significantly greater than that at all other time points (P<.05). In the lateral flank group, a significant increase in cuff pressure was observed after position (T2; P<.05). Over time, a decrease in cuff pres-

Table 1. Demographic data (n=200).

	Supine	Prone	Lateral Flank	Lithotomy
Age	**44.1 (16.4)**	48.1 (12.8)	54.5 (12.5)	54.0 (15.4)
Gender (M/F)	43 / 7	34 / 16	40 / 10	35 / 15
Size (cm)	173.4 (5.5)	168.7 (8.9)	172.2 (8.9)	170.1 (9.9)
Measured body weight (kg)	79.7 (11.6)	79.1 (14.2)	78.6 (13.4)	76.9 (11.4)
BMI (kg/m²)	26.5 (3.8)	27.8 (4.5)	26.4 (3.4)	26.56 (3.1)
Duration of anesthesia (min)	85.9 (43.8)	112.7 (33.4)	116.1 (45.1)	56.8 (17.7)
Duration of surgery (min)	**71.9 (40.7)**	91.9 (31.7)	95 (43.2)	**44.5 (15.6)**

Data are number and position or mean (SD).

Table 2. Incidence of sore throat, cough, hoarseness at the postoperative 2nd hour in the study patients undergoing surgery in different positions (n=200).

	Supine (n=50)	Prone (n=50)	Lateral flank (n=50)	Lithotomy (n=50)
Sore throat	2 (4%)	4 (8%)	5 (10%)	-
Cough	2 (4%)	5 (10%)	4 (8%)	2 (4%)
Hoarseness	-	2 (4%)	2 (4%)	2 (4%)

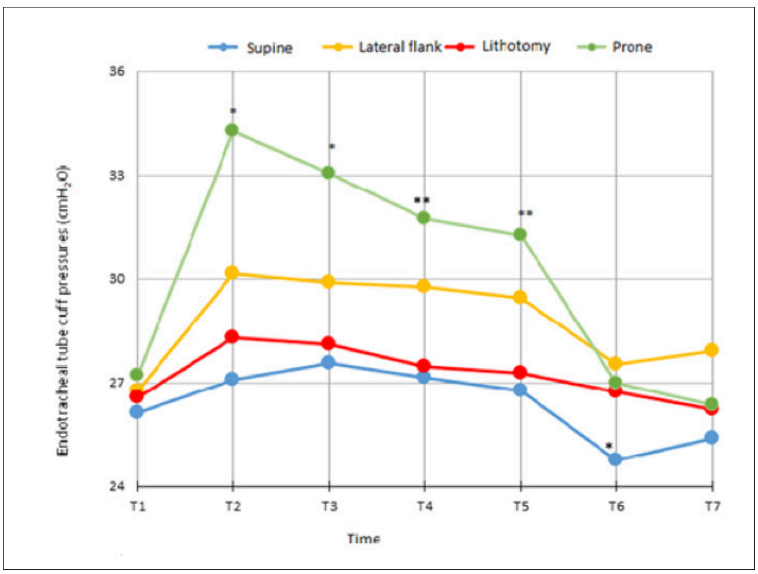

Figure 1. Variation of endotracheal tube cuff pressures according to positions during the operation.

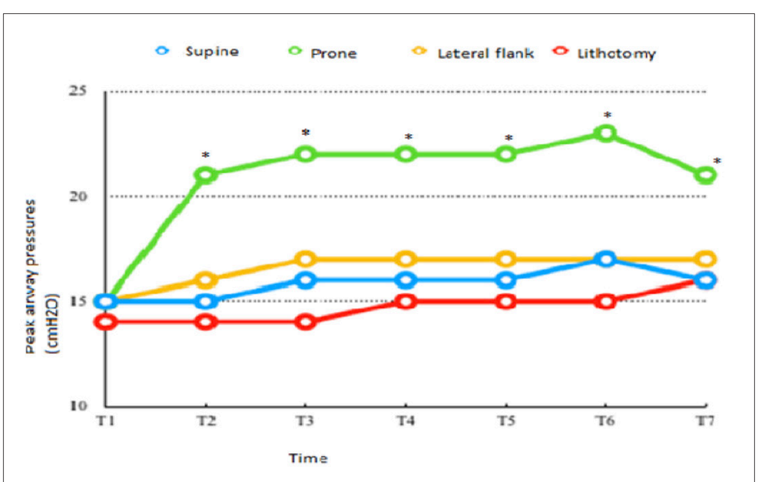

Figure 2. Variation of peak airway pressures according to positions during the operation.

sure values was observed; however, significant differences were observed between cuff pressures measured at T1, T3, T4, and T5. In the lithotomy group, the T2 and T3 mean cuff pressure values were significantly higher than the T1 values ($P<.05$) (**Figure 1**).

When comparing the mean cuff pressure values between groups, T2 values in prone and lateral flank groups were significantly higher compared to supine groups, and T2 and T3 values in the prone group were significantly higher compared to the other three groups. No statistically significant differences were observed between the other groups (**Figure 1**). Furthermore, T4 and T5 cuff pressure values were significantly higher in the prone group compared to supine and lithotomy groups ($P<.05$). All groups had comparable cuff pressure values at the end of surgery (T6) and before extubation (T7).

In supine group, peak airway pressure (PAP) was increased over time, but no significant increase was observed at T2; also, the PAP value measured at T6 and T7 was significantly higher compared to T1 ($P<.05$). In the prone group, the PAP values measured at T2 and subsequent measurements (T3 through T7) were significantly higher compared to the T1 value ($P<.05$). In the lithotomy group, there was no significant difference in the PAP values measured before (T1) and after the position change (T2), but the PAP values measured at T5, T6, and T7 were significantly higher compared to T1 ($P<.05$). All groups were comparable in terms of T1 PAP values (**Figure 2**).

At the 2nd postoperative hour, all groups were comparable regarding the incidence of sore throat, hoarseness, and cough at ($P>.05$). At the 12th postoperative hour, no patients complained of hoarseness or sore throat; only one patient experienced a cough (**Table 2**).

We compared patients with and without postoperative sore throats and found statistically significant differences in terms of cuff pressure, anesthesia duration, and operation duration ($P<.05$).

DISCUSSION

The post positioning cuff pressure was significantly increased in the lithotomy, lateral flank, and prone positions than the prepositioning values, with the greatest increase in the prone group. Subsequently, the cuff pressure decreased over time, and incidences of postoperative sore throat, cough, and hoarseness were similar in all groups.

The ETT cuff primarily aims to stop leakage during positive pressure ventilation and prevent pharyngeal content aspiration. Some studies recommended a minimum safe cuff pressure of at least 25 cmH_2O for this purpose.[12,13] In contrast, studies examining the relationship between cuff pressure and capillary perfusion in the tracheal mucosa suggested a cuff pressure of <30 cmH_2O.[14,15] Despite these recommended target cuff pressure values, anesthesiologists clinically tend to determine the cuff inflation pressure based on the sound of a leak or by palpation. In many cases, cuff pressure used in clinical practice exceeds the recommended range, and anesthesiologists' experience is not considered a significant factor in achieving the target cuff pressure values.[16-18] In our study, the initial mean cuff pressure value achieved by inflating the ETT cuff using the palpation method was measured as 48 (22) cmH_2O (range:10-120 cmH_2O), which is higher than the recommended safe cuff pressure value.

Changes in intraoperative positioning of patients causes ETT displacement in trachea and cuff pressure changes.[19,20] Kim et al reported that when patients were transitioned from the supine to a prone position while keeping the head in a neutral position, approximately 90% patients experienced an increase in cuff pressure.[11] Likewise, Athiraman et al reported that cuff pressures decreased over time in supine and prone groups in their study who had undergone neurosurgical surgeries in supine, prone, lateral, or sitting positions.[5] Furthermore, they noted significant differences in cuff pressures measured at all time points between in two groups as follows: between the initial cuff pressure and extubation in supine group, and between the initial cuff pressure and postposition, end of the procedure, and pre extubation in prone group. We also observed a significant increase in cuff pressure at T2 in the prone group, which was substantially higher compared to the other three groups. Moreover, despite the gradual decrease in cuff pressure (at T3, T4, and T5), it remained considerably higher than the T1 value.

As yet, there is no conclusive evidence regarding factors affecting cuff pressure in a prone position and the reason for an increase in cuff pressure in this position. The anatomical structure of the neck and increased intrathoracic pressure in prone positions are potential contributing factors. The trachea is located anteriorly in the neck and is subjected to gravitational pressure from the cervical spine, neck muscles, and major blood vessels in prone position.[21] Furthermore, the C-shaped hyaline cartilage rings in the trachea are present anteriorly; because of the absence of cartilaginous support to the posterior tracheal wall, it can be easily compressed in this position. Moreover, pillows used in the prone position can increase intrathoracic pressure, leading to higher cuff pressure and airway pressure during inspiration in patients receiving mechanical ventilation

When transitioning from supine to lateral flank position, ETT displacement can lead to changes in cuff pressure. Kim et al reported a significant increase in cuff pressure in patients undergoing urological surgery in lateral flank position.[22] A similar effect with transitioning to lateral flank position was observed in our study. The following factors may contribute to this phenomenon: tracheal compression caused by the weight of the overlying mediastinal structure, decreased compliance and functional residual capacity of the lower lung, and potential cuff pressure changes due to cephalad migration of the ETT after the position was changed.

Kako et al examined the relationship between the duration of surgery and changes in cuff pressure and reported that 93% of patients developed a gradual decrease in cuff pressure over time.[23] Moreover, the cuff pressure significantly varied with operative time, particularly during prolonged surgeries. In our study, a similar decrease in cuff pressure was observed in all groups with the most significant decrease being in the prone group. This decrease in cuff pressure over time may be attributed to loss of consciousness and reduction in neck muscle tone because of general anesthesia.

A significant positive correlation has been reported between cuff pressure and increased PAP.[24] In our study, there was a significant post positioning increase in PAP in prone and lateral flank groups, of which the prone group had the highest value. Moreover, the trend of decreasing cuff pressure observed during the operation did not correspond to the trend in PAP, i.e., in the lithotomy group, PAP increased over time. In mechanical ventilation, if positive end expiratory pressure is not applied during expiration, the airway pressure drops to zero. Therefore, we measured cuff pressure at the end of expiration to eliminate the effect of increased airway pressure. Regular monitoring of cuff pressure during follow-ups is important in patients with persistently high airway pressure owing to its correlation with PAP.

Throat pain is one of the most common postoperative airway complications, with an incidence of

14-55%.[25] Young age, female gender, operation and anesthesia duration, intubation conditions, ETT diameter, cuff type, cuff pressure, and displacement intraoperatively have been identified as contributing factors to postoperative throat pain.[26]

Presumably, inflammation after intubation is influenced by the release of proinflammatory mediators from the tracheal mucosa because of ischemia in the tracheal mucosa or oropharynx.[27] During operation, mucosal blood flow can be impaired due to the mechanical abrasions caused by high cuff pressure of the ETT on the tracheal mucosa, leading to laryngeal stenosis. Liu et al examined correlation between ETT cuff pressure and postoperative complications and found a significantly higher incidence of throat pain, hoarseness, and blood staining in the group where cuff pressure measurements were not performed.[28] The study also demonstrated a significant correlation between prolonged operation duration and throat pain.

In our study, postoperative throat pain was observed in only 11 (5.5%) patients, hoarseness in 6 (3%) patients, and cough in 13 (6.5%) patients, with no significant difference in the incidence of symptoms among different positions. We believe that setting postintubation cuff pressure to 25 cmH_2O may have helped limit the incidence of postoperative symptoms to a small number of patients only. In patients experiencing postoperative throat pain, the mean postposition cuff pressure, anesthesia and operation duration were significantly higher compared to those who did not. Similarly, patients with postoperative cough had significantly higher mean postposition cuff pressure compared to those without cough. The limitation of our study is that we used ETT from a single manufacturer. Therefore, our findings may not be applicable to other types of ETT.

In conclusion, because ETT cuff pressure is a dynamic phenomenon affected by changes in patient positioning, regular monitoring and adjustment of the cuff pressure while changing positions is as essential as other vital signs in anesthesia practice to ensure patient safety. Based on these results, a properly calibrated manometer should be used to control the cuff pressure instead of conventional nonobjective methods, such as touch controls.

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