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Comparison of Endotracheal Tube Stabilization Methods in Patients Undergoing Prone Position: A Prospective Study

Pron Pozisyona Alınan Hastalarda Endotrakeal Tüp Sabitleme Yöntemlerinin Karşılaştırması: Prospektif Çalışma

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ABSTRACT Objective: We aimed to assess the impact of endotracheal tube (ETT) fixation methods routinely used in our clinic, on displacement in prone-positioned patients under general anesthesia. **Material and Methods:** One of four different methods (Thomas™ tube holder, nonadhesive tape, X-shape adhesive tape, and Reinforced adhesive tape) was used for ETT fixation. The distance between the tip of the ETT and the carina was measured using a fiberoptic bronchoscope (FOB) in the supine position. The patients were then placed in the prone position, and the FOB examination was repeated. The difference between these two measurements, obtained in the supine and prone positions, indicated the ETT displacement due to position changes. Clinically significant displacement was defined as ETT movement of >1 cm in either direction. **Results:** A total of 80 patients were included in this study. ETT displacement occurred in 31 (38.75%) patients during the transition to the prone position. The least displacement was observed with the Thomas™ tube holder (0.2±0.52). Reinforced adhesive tape showed similar results to the Thomas™ tube holder (0.4±1.19). The highest ETT displacement was observed with X-shape adhesive tape (1.6±1.79) and nonadhesive tape (0.95±1.05), respectively. Clinically significant ETT movement (>1 cm) occurred in 17 patients (21.25%). The occurrence rates were 5% (1/20) with the Thomas™ tube holder, 15% (3/20) with Reinforced adhesive tape, 25% (5/20) with nonadhesive tape, and 40% (8/20) with X-shape adhesive tape. **Conclusion:** The Thomas™ tube holder significantly reduced ETT mobility in patients positioned in the prone position.

Keywords: Anesthesia; endotracheal intubation; prone position

ÖZET Amaç: Bu çalışmada, kliniğimizde rutin olarak kullanılan endotrakeal tüp (ETT) fiksasyon yöntemlerinin, genel anestezi altında pron pozisyondaki hastalarda ETT yer değiştirmesi üzerindeki etkisini değerlendirmeyi amaçladık. **Gereç ve Yöntemler:** ETT fiksasyonu için 4 farklı yöntemden (Thomas tüp tutucu, yapışkan olmayan bağ, X şeklinde yapışkan bant ve güçlendirilmiş yapışkan bant) biri kullanıldı. Supin pozisyonda, ETT ucu ile karina arasındaki mesafe fiberoptik bronkoskop (FOB) ile ölçüldü. Daha sonra hastalar pron pozisyona alındı ve FOB muayenesi tekrarlandı. Supin ve pron pozisyonunda elde edilen bu iki ölçüm arasındaki fark, pozisyon değişikliklerine bağlı ETT yer değişikliğini gösterdi. Klinik olarak anlamlı bir yer değiştirme, ETT'nin her iki yönde de >1cm hareketi olarak tanımlandı. **Bulgular:** Bu çalışmaya toplam 80 hasta alındı. Pron pozisyona geçişte, 31 (%38,75) hastada ETT yer değişikliği meydana geldi. En az ETT yer değişikliği Thomas tüp tutucu ile gözlendi (0,2±0,52). Güçlendirilmiş yapışkan bant yöntemi (0,4±1,19) Thomas tüp tutucuya yakın sonuç verdi. En yüksek ETT yer değişikliği sırasıyla X şeklinde yapışkan bant yöntemi (1,6±1,79) ve yapışkan olmayan bağda (0,95±1,05) görüldü. Klinik olarak anlamlı ETT hareketi (>1 cm), 17 (%21,25) hastada tespit edildi; bu oran Thomas tüp tutucuda %5 (1/20), güçlendirilmiş yapışkan bant yönteminde %15 (3/20), yapışkan olmayan bağda %25 (5/20) ve X şeklinde yapışkan bant yönteminde %40 (8/20) idi. **Sonuç:** Pron pozisyona alınan hastalarda Thomas tüp tutucu, ETT hareketliliğini önemli ölçüde azaltmıştır.

Anahtar Kelimeler: Anestezi; endotrakeal entübasyon; pron pozisyon

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The endotracheal tube (ETT) is commonly used to secure the airways of patients under anesthesia. However, during patient transfers or position changes, unexpected extubation or selective bronchial intubation may occur due to tube displacement.[1] This scenario can result in serious complications, including injuries to the larynx, infections, damage to the epithelial tissues, vocal cord trauma, bronchospasm, respiratory failure, and in severe cases, even death. Even a displacement of more than 1 cm of the ETT can compromise the airway, making it crucial to ensure proper placement and securement of the ETT to reduce such adverse events. For this purpose, various methods are used in clinical practice to secure the ETT, including adhesive tape, nonadhesive tape, and commercial ETT holders.[2] However, there is still no consensus on the most effective method for ETT stabilization.[1]

The prone position is commonly used in various surgeries when access to posterior structures is required. However, in this position, access to anterior structures is limited, which can lead to challenges in airway management. In patients in this position, the risk of displacement of the ETT is high due to patient positioning, traction on the ventilator tubing, or the effects of gravity.[3]

We aimed to evaluate the effects of four different ETT fixation methods, routinely used in our clinic, on ETT displacement in patients placed in the prone position under general anesthesia. We believe this study could provide additional data to the studies comparing and measuring different ETT fixation methods.

MATERIAL AND METHODS

This study was approved by the Clinical Research Ethics Committee of Dışkapı Yıldırım Beyazıt Training and Research Hospital, University of Health Sciences Türkiye (date: July 18, 2022; no: 142/05) and was registered at ClinicalTrials.gov (NCT05643053). The study adhered to the guidelines outlined in the Declaration of Helsinki, and written consent was acquired from every participant involved in the trial.

Patients who were planned for prone-position surgeries under general anesthesia between September 1, 2022, and September 9, 2023, were enrolled in the study. Exclusion criteria were patients who declined to participate, those with mustaches or beards, dental loss, restricted neck movements, restricted mouth opening and airway malformation. Also patients who have including conditions like gastroesophageal reflux, hiatal hernia, and a history of gastric surgery, gastrointestinal motility disorders, and temporomandibular joint disorders were excluded for risk of aspiration.

Standard monitoring included noninvasive arterial blood pressure, electrocardiography, and peripheral O_2 saturation. Patients were preoxygenated with a mask delivering 100% oxygen at 5 L/min for at least 3 minutes, ensuring an end-tidal oxygen level of 90%. All patients received a standardized general anesthesia induction. Intubation was performed by an experienced anesthetist using a direct laryngoscope with a 3-4 size Macintosh blade and an ETT (Nextech, İstanbul, Türkiye). For male patients, an ID 8.0 ETT was used, and for female patients, an ID 7.5 tube was used. The Intubation Difficulty Scale (IDS) was used to evaluate the level of difficulty during intubation. The anesthetist verified the placement of the tracheal tube by observing its passage through the vocal cords and ensuring it was positioned between the designated markings on the tube. The tracheal placement was further confirmed by bilateral chest auscultation and the detection of end-tidal CO_2. Special attention was given to ensuring the anatomical midline position of the tongue. The tube depth was measured using the scale on the tube at the upper incisors. To prevent excessive pressure on the tracheal mucosa and gas leakage from the airway, the ETT cuff pressure was inflated to 25 cm H_2O using a manometer (VBM Medizintechnik, GmbH, Germany).

Patients were assigned to one of four groups through a closed-envelope randomization method. Four different ETT fixation methods were used.

- **Thomas™ tube holder (Laerdal, Wappingers Falls, New York)**

- **Nonadhesive tape:** A 12 mm woven cotton cloth tape, cut into one-meter strips, was tied around the ETT. The tape was wrapped around the patient's head and secured with a reef knot at the left corner of the mouth. The ends of the tape were then wrapped around the ETT and secured with a reef knot.

- **X-shape adhesive tape:** Two pieces of adhesive tape, each 2×30 cm in size, were wrapped around the ETT-one around the maxilla and the other around the mandible-and then secured in place.

- **Reinforced adhesive tape:** After applying the X-shaped adhesive tape, 2 additional 2×30 cm long strips were placed across the other tapes for reinforcement.

Benzoin was not used. All ETT fixations were secured on the left side, and the insertion depth was checked at the level of the upper incisors.

After intubation and fixation of the ETT using one of four different methods, a standard research protocol was followed. While the patient was in the supine position, the ventilator circuit was disconnected from the tube, the cuff was deflated, and the distance between the tip of the tube and the carina was measured using a fiberoptic bronchoscope (FOB) (Karl Storz/Germany, Tuttlingen, Germany, 11302BD2). The tip of the FOB was advanced to the carina, and this point was marked on the FOB. Then, the FOB was retracted to the tip of the ETT, and a second mark was made on the FOB. The distance between these two marks on the FOB represented to the distance from the tip of the ETT to the carina (ETT-carina distance). This measurement in the supine position was called D1. Afterward, the patients were turned into a prone position. The patients' heads, eyes, ears, and noses were supported with an appropriate pillow to prevent pressure. The ETT cuff pressure was checked, and the FOB examination was repeated. This measurement was recorded as D2. The difference between these two measurements obtained in the supine and prone positions (D1-D2) indicated the displacement of the ETT due to positional changes. The tubes were secured to the operating table to minimize the possibility of tube movement that could cause traction on the ETT. Notable displacement was described as any movement of the ETT exceeding 1 cm in any direction.[4] During the procedure, the patient's position was neutral, and neither Trendelenburg nor reverse Trendelenburg positions were applied.

STATISTICAL ANALYSIS

The sample size was determined using a one-way analysis of variance (ANOVA) test for the differences between tube taping methods regarding tube displacement. With a Type-I error rate of 0.05, a total of 76 patients were needed to detect a large effect (Cohen's f=0.40) between groups with 80% power. Allowing for a 5% missing rate, 80 patients were assigned to the four tube taping methods concerning tube displacement. The sample size calculation was performed using G*Power version 3.1.9.7 (Franz Faul Universital Kiel, Germany).

Numerical data were summarized as mean±standard deviation along with median (minimum-maximum), whereas frequency and percentage were used for categorical data. One-way ANOVA or Kruskal-Wallis test was used to compare tube taping methods regarding a numerical variable, according to normality assumption. When a p-value from Kruskal-Wallis test was statistically significant, the Thomas™ tube holder method was compared to the other three methods pairwise by Mann-Whitney U test. Bonferroni-corrected p-values were used for Mann-Whitney U test. Chi-square or Fisher's exact test was used to compare groups regarding categorical data. Spearman's rho was used to assess the correlation between two numerical variables. A p value of <0.05 was considered statistically significant. Analyses were performed with R statistical language version 4.4.0 (R foundation for statistical computing, Vienna, Austria).

RESULTS

The study included a total of 80 patients, with 20 patients in each group. The average age of the patients was 46.9 years, and the body mass index was 28.18±5.38, with 47.5% of the patients being male. No differences were observed between the groups regarding demographic data, American

Society of Anesthesiologists classification, and comorbidities. In the preoperative assessments of the patients, no significant differences were found in Mallampati scores (both p>0.05). The IDS scores of the intubated patients were also similar (p=0.375). No significant differences were found in the sternomental distance, thyromental distance, and hyoid height (p=0.955, p=0.618, and p=0.618, respectively) (Table 1).

The tracheal tube was secured at a median distance of 21.0 cm (19-23.0 cm) from the left corner of the mouth, with no significant differences between groups (p=0.053). After transitioning from the supine to the prone position, 31 (38.75%) patients experienced ETT displacement, with significant differences between groups (p<0.001). The ETT displaced the least with the Thomas™ tube holder (0.2±0.52). Reinforced adhesive tape showed results close to those of the Thomas™ tube holder (0.4±1.19). The highest ETT displacement was observed with X-shape adhesive tape (1.6±1.79) and nonadhesive tape (0.95±1.05), respectively. Clinically significant ETT movement (greater than 1 cm) was observed in 17 patients (21.25%). The percentages of clinically significant displacement were 5% (1/20) with the Thomas™ tube holder, 15% (3/20) with reinforced adhesive tape, 25% (5/20) with nonadhesive tape, and 40% (8/20) with X-shape adhesive tape (Table 2).

The correlations between ETT displacement and measurements such as sternomental distance, thyromental distance, and hyoid height were not statistically significant for any of the methods. The correlation coefficients (Spearman's rho) and p values indicate no strong association between these measurements and tube displacement for any of the taping methods (Table 3).

In the X-shape adhesive tape group, unexpected extubation occurred in one patient. The patient was re-intubated without complications. Postoperative sore throat Numerical Rating Scale was not significantly different (p=0.127). Additionally, hoarseness was observed in one patient in the X-shape adhesive tape group.

TABLE 1: Demographic data and pre-operative characteristics.

Variables	Thomas™ tube holder	Reinforced adhesive tape	X-shape adhesive tape	Nonadhesive tape	p value
Age (years)	47.3±13.3	43.9±11.81	46.6±12.8	49.8±11.27	0.511
Male n (%)	10 (0.5)	11(0.55)	3 (0.15)	14 (0.7)	0.005
BMI (kg/m^2)	28.81±5.75	29.89±9.48	28.49±6.07	27.15±4.39	0.638
Comorbidity, n (%)	6 (0.3)	4 (0.2)	9 (0.45)	9 (0.45)	
Asthma	1 (0.05)	1 (0.05)	0	1 (0.05)	
Hypertension	3 (0.15)	3 (0.15)	7 (0.35)	5 (0.25)	
Diabetes mellitus	2 (0.1)	2 (0.1)	2 (0.1)	3 (0.15)	
Thyroid dysfunction	2 (0.1)	1 (0.05)	3 (0.15)	1 (0.05)	0.266
CAD	2 (0.1)	0	2 (0.1)	1 (0.05)	
Rheumatoid arthritis	1 (0.05)	0	0	1 (0.05)	
Chronic renal failure	1 (0.05)	0	0	0	
Current smoking	11 (0.55)	8 (0.4)	7 (0.35)	13 (0.65)	0.228
Mallampati grade, n (%)					
Class I	13 (65)	14 (70)	17 (85)	11 (55)	0.181
Class II	7 (35)	6 (30)	3 (15)	9 (45)	
Sternomental distance (cm)	21.3±3.79	20.65±5.37	20.5±5.88	20.63±3.73	0.955
Thyromental distance (cm)	9.18±1.74	8.53±3.24	8.95±2.26	9.13±1.55	0.803
Hyoid height (cm)	6.43±2.64	5±1.46	6.05±1.5	5.98±1.13	0.081

Values are given as mean±standard deviation or number (percentage); BMI: Body mass index; CAD: Coronary artery disease.

TABLE 2: Changes in parameters according to supine to prone positioning change.

Variables	Thomas™ tube holder	Reinforced adhesive tape	X-shape adhesive tape	Nonadhesive tape	p value
ETT level during supine position (cm)	21.05±0.88	20.8±1.47	21.4±0.6	21.55±0.51	0.053
ETT level during prone position (cm)	21.55±1.5	21.05±1.7	21.1±2.33	21.55±1.27	0.490
ETT-to-carina distance in the supine position (D1), cm	3.25±1.68	3.65±2.28	2.35±1.66	3.1±1.48	0.09
ETT-to-carina distance in the prone position (D2), cm	3.05±1.54	3.45±1.96	2.95±2.14	3.05±1.57	0.780
ETT movement related to positioning change (cm)*	0.2±0.52	0.4±1.19	1.6±1.79	0.95±1.05	<0.001
>1 cm ETT displacement, n (%)	3 (15)	1 (5)	8 (40)	5 (25)	<0.01
Unexpected extubation	0	0	1	0	1
Postoperative sore throat NRS	1.3±0.47	1.35 ±0.58	1.25±0.55	1.1±0.3	0.127
Postoperative hoarseness	0	0	1	0	1
Intubation Difficulty Scale	1.5±1	1.1±1.0	1.15±1.31	0.95±0.83	0.375

Values are given as mean±standard deviation or number (percentage). *The tube movement was measured by the difference between D1 and D2; ETT: Endotracheal tube; NRS: Numerical Rating Scale.

TABLE 3: Correlation between endotracheal tube displacement and patients' characteristics according to position change.

Variables		Thomas™ tube holder	Reinforced adhesive tape	X-shape adhesive tape	Nonadhesive tape
Sternomental distance (cm)	r value	0.18	0.11	-0.29	0.08
	p value	0.447	0.636	0.211	0.75
Thyromental distance (cm)	r value	-0.11	0.12	-0.28	-0.13
	p value	0.637	0.601	0.225	0.579
Hyoid height (cm)	r value	0.21	0.11	0.17	0.03
	p value	0.372	0.65	0.476	0.884

DISCUSSION

This study investigated the effectiveness of different methods for stabilizing the ETT in patients who transitioned from the supine to the prone position. Therefore, the advantages and disadvantages of methods used for ETT fixation, such as adhesive tape, binding techniques (nonadhesive tape), reinforced adhesive tape, and the Thomas™ tube holder were evaluated in detail. Our findings indicate that the Thomas™ tube holder significantly reduced ETT mobility and provided better fixation compared to other methods.

In clinical anesthesia practices, preventing ETT displacement and minimizing related complications is a critical priority for patient safety. The incidence of unexpected extubation or ETT displacement has been reported to range from 43% to 62.4% across all different fixation methods.[5] In this study, ETT displacement occurred in 38.75% of patients when transitioning to the prone position. Of these, 21.25% experienced clinically significant ETT movement (>1 cm). Previous studies have shown conflicting results regarding the impact of transitioning from the supine to the prone position on ETT movement.[6,7] Minonishi et al. reported that ETT displacement occurred in 91.7% of patients during the transition to the prone position, with ETT movement ≥10 mm observed in 21.25% of cases.[6] In contrast, Ahamed et al. concluded that ETT did not displace in patients after transitioning from the supine to the prone position.[7] However, these studies did not specify the method used for ETT fixation. Nevertheless, the prone position may complicate the prediction of ETT movement. Although the exact mechanism is unclear, unpredictable neck rotation effects may contribute to ETT displacement during the transition to the prone position.[6] In adults, turning the head towards the tube fixation side may pull the ETT tip backward when the fixation site is at one corner of the mouth. Conversely, during head rotation contralateral to the fixation side, the tube's movement can vary depending on the degree of rotation and the size of the patient's mouth. In this study, the ETT was secured at the left corner of the mouth, and the patient was positioned prone with the head turned to the opposite side. The greatest ETT movement was observed in the X-shape adhesive tape group, where the average ETT displacement was 16 mm away from the carina. Our findings are consistent with previous studies.[8] Given that the anterior branch of the recurrent laryngeal nerve lies approximately 10 mm beneath the vocal cords, displacement of the ETT may have clinically significant consequences for adult patients.[6] Therefore, it is essential to carefully select and regularly monitor fixation methods to maintain the stability of the ETT, especially during position changes.

There is no universally accepted optimal method for ETT fixation among the available techniques. However, in clinical practice, adhesive tape remains the most commonly used fixation material, with the X-shape adhesive tape method being particularly prominent in its application.[5] The effectiveness of adhesive tapes can vary significantly depending on environmental factors, particularly temperature.[2] For example, high temperatures can diminish the adhesive properties of tapes, leading to inadequate stabilization of the tube. Conversely, at low temperatures, tapes may become rigid and cause skin irritation Additionally, factors such as facial hair, sweating, and saliva may affect the adhesive properties of tapes, reducing the reliability of the application.[9] Therefore, considering that adhesive tapes are significantly affected by temperature, humidity, and other environmental conditions, reinforcing these tapes with additional strips may lead to more reliable results in ETT fixation.[10] In the current study, the greatest ETT displacement occurred with the X-shape method of fixation. However, the use of reinforced adhesive tape (enhanced with another tape in the X-shape) demonstrated effects closest to those of the Thomas™ tube holder in ETT fixation. Therefore, considering that adhesive tapes are significantly affected by temperature, humidity, and other environmental conditions, reinforcing these tapes with additional strips may lead to more reliable results in ETT fixation.

Another commonly used method for ETT fixation is the binding technique. Compared to adhesive tape method, this technique has been reported to significantly reduce tube movement.[9] However, this method has some disadvantages, such as the risk of airway obstruction and potential damage to venous structures.[11] Additionally, soaking the knots for just five minutes has been found to significantly increase the risk of slippage.[12] In such cases, it is also difficult to loosen or readjust the binding, and it often requires cutting the binde from the ETT.[11] Choosing a safe and effective method for ETT stabilization is critical for patient safety and continuity of ventilation. Therefore, the application difficulties and possible complications of this method should be carefully evaluated in clinical practice, and one should be prepared for potential issues when using this technique.

In recent years, the Thomas™ tube holder has played a significant role in ETT stabilization. The Thomas™ tube holder prevents tube slippage by securing the ETT with a plastic screw, potentially allowing for a more stable ventilation process. The concern about airway obstruction caused by knots in the binding method is reduced with the Thomas™ tube holder due to the relatively large surface area of the screw clamp.[11] When using the adhesive tape method, forces exerted on a taped ETT can cause distortion and tension in the surrounding soft tissues, which may lead to considerable ETT movement even if the adhesive remains intact. Conversely, an ETT secured with the Thomas™ tube holder is stabilized between firm bony structures, which remain stationary under such forces.[4] Additionally, due to its surface structure, the Thomas™ tube holder is more resistant to contamination from blood, vomit, or other impurities on the patient's face.[13] This resistance can help prevent tube displacement and related complications, especially in situations where airway access is difficult, such as in the prone position. Studies have observed that the Thomas™ tube holder significantly reduces the risk of ETT displacement and unexpected extubation.[14] However, many previous studies have been conducted on human cadavers or plastic simulation mannequins, reducing the applicability of the results to real-life scenarios. In the current study, we observed that the Thomas™ tube holder significantly reduced ETT displacement. Our protocol involved using FOB to assess the distance between the ETT tip and the carina, allowing us to accurately determine the ETT's movement within the airway. Previous research has used indirect measures to estimate ETT movement within the airway, including the distance from the incisors or lips.[4] Additionally, the use of neuromuscular blockade in the study allowed for a clearer demonstration of the device's role in ETT stabilization by reducing the impact of external factors.

This study's several potential limitations warrant consideration. To begin with, our study lacked blinding with respect to the various intervention groups. Due to the characteristics of the device, we determined that blinding would not be practical. Additionally, methods like adhesive tape, binding, and the Thomas™ tube holder may not always ensure reliable fixation. While these methods can be standardized and controlled in a laboratory environment, the variability in patient anatomy, clinical conditions, and application techniques can lead to differences in fixation effectiveness when used in actual patient care. Ultimately, we excluded patients who were edentulous or had loose teeth from the study. In the future, it would be interesting to evaluate the effectiveness of the Thomas™ tube holder in special patient groups, such as edentulous patients or those with loose teeth.

CONCLUSION

In conclusion, the Thomas™ tube holder significantly reduced ETT mobility compared to other methods. We believe that the superior performance, ease of use, and reliability of the Thomas™ tube holder make it a valuable piece of equipment, particularly in critical patient care situations where ensuring airway security can be challenging, such as in the prone position.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Funda Atar, Savaş Altınsoy; **Design:** Savaş Altınsoy, Funda Atar; **Control/Supervision:** Jülide Ergil, Savaş Altınsoy; **Data Collection and/or Processing:** Funda Atar; **Analysis and/or Interpretation:** Funda Atar; **Literature Review:** Yusuf Özgüner; **Writing the Article:** Funda Atar; **Critical Review:** Jülide Ergil; **References and Fundings:** Yusuf Özgüner; **Materials:** Funda Atar.*

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