Laboratory Report

Taping methods and tape types for securing oral endotracheal tubes

Nileshkumar Patel MD,
Charles E Smith MD FRCPC,
Alfred C Pinchak PE MD PHD,
Donald E Hancock AEET

Purpose: To evaluate tapes and taping methods with respect to the minimum force required to dislodge endotracheal tubes (ETTs).

Methods: A simulated face model consisting of a section of PVC pipe was used. The ETT was attached to a piezo-electric force transducer and pullout force was manually applied in a vertical, right or left direction. Five tape types were tested: Curity, Leukosilk, Hy.tape, Leukopore, and Transpore. Seven taping methods were used to secure the ETT. The methods differed with respect to tape width and whether the tape was split along its longitudinal axis. Each taping condition was replicated 20 times (7 methods × 5 tapes × 3 directions) for a total of 2100 pullout tests.

Results: Minimum forces to dislodge ETTs were higher (P <0.05) with Curity tape (mean ± SD: 135 ± 75 N) than with the other tapes (Leukosilk: 93 ± 51 N, Hy.tape: 78 ± 34 N, Leukopore: 47 ± 32, and Transpore: 37 ± 23 N). The most secure taping method was achieved by taping the ETT, using 2.5 cm wide Curity tape, in a circumferential fashion to both the upper and lower borders of the simulated mouth opening, and reinforcing these tapes with two strips applied longitudinally across the borders of the mouth opening (method 7). Taping methods which involved splitting the tape along its longitudinal axis resulted in lower minimal pullout forces whenever the pullout force was directed towards the side of attachment (P <0.05 *vs* right and vertical direction).

Conclusion: There are differences in ETT pullout forces and mechanisms of dislodgement depending on taping method and tape type.

Objectif : Évaluer les rubans adhésifs et leurs modes d'ancrage par rapport à la force minimale requise pour déloger un tube endotrachéal (TET).

Méthodes : Un modèle de face simulé constitué d'une section de tube en CPV a été utilisé. Le TET était relié à un transducteur de force piézo-électrique et on appliquait sur le tube une traction verticale, vers la droite ou vers la gauche. Cinq marques de ruban adhésif ont été testées : Curity, Leukosilk, Hy.tape, Leukopore et Transpore. Sept méthodes d'ancrage ont été utilisées pour la rétention du TET conformément à la largeur du ruban et selon qu'il était divisé sur son axe longitudinal ou non. Chaque méthode d'ancrage était mise à l'épreuve 20 fois (7 méthodes x 5 rubans x 3 directions) pour un total de 2100 tests.

Résultats : Avec le ruban Curity, la traction minimale requise pour déloger le tube était plus élevée (P <0,05) (moyenne ± ET : 135 ± 75 N) qu'avec les autres rubans (Leukosilk 93 ± 52 N, Hy.tape 78 ± 34 N, Leukopore 47 ± 32 N et Transpore 37 ± 23 N). La méthode la plus efficace pour l'ancrage du TET consistait à faire le tour du tube avec deux rubans Curity de 2,5 cm de large et de les fixer à la commissure du modèle buccal et de les renforcer avec deux rubans appliquées logitudinalement à travers les limites de l'ouverture buccale (méthodes 7). Les méthodes d'ancrage consistant à séparer le ruban en deux sur son axe longitudinal ont été les moins efficaces lorsque que la force d'extraction était dirigée du côté de l'attache (P <0,05 *vs* direction droite ou verticale).

Conclusion : la force requise pour déloger un TET et les mécanismes de déplacement sont différents selon la méthode d'ancrage et le type de ruban adhésif utilisé.

From the Department of Anesthesiology, Case Western Reserve University, MetroHealth Campus, 2500 MetroHealth Drive, Cleveland, Ohio 44109, USA.

Address correspondence to: Dr. C.E Smith.

Presented in part at the Cleveland Society of Anesthesiologist's Annual Meeting, February, 1995, and at the American Society of Anesthesiologists Annual Meeting, Atlanta, October, 1995.

Accepted for publication November 9, 1996.

ACCIDENTAL tracheal extubation is an uncommon event in the practice of modern anaesthesia. However, loss of the airway due to inadequately secured endotracheal tubes (ETTs) can occur, and can lead to major morbidity and mortality.[1] The most frequently used method of securing ETTs in the operating room setting is by means of taping the ETT to the face. Despite the millions of ETTs being taped annually by anaesthetists, there is a lack of consensus on the best method of taping these tubes. Neither is there agreement on the most appropriate tape for securing the tube. Such a lack of data is, in part, due to absence of models appropriate for these studies. The purpose of the present study was to compare the forces required to dislodge ETTs secured with seven different taping methods and five different types of tape. The study used a simulated PVC model of a face that would allow for adherence of standard tapes as well as be able to withstand repeated testing. This model has previously been used to measure dislodgement forces and mechanism of dislodgement during simulated accidental pullout of intravenous catheters.[2]

Methods

Face Model

The face model consisted of a section of hard PVC pipe (8.8 cm outer diameter, 3 mm thick) in place of a patient's face. An oval shaped 2 cm x 5 cm hole was drilled through the hollow PVC pipe in order to simulate the shape of an open mouth.

Taping Methods

An 8.0 I.D. ETT (Mallinckrodt Medical, St Louis, MO) was placed in and taped to the left corner of the oval mouth. Seven methods of securing the ETT in use at MetroHealth Medical Center, Cleveland, Ohio were evaluated as follows: 1. A single 1.25 cm x 30 cm tape was attached to the upper border of the PVC face after wrapping twice around the ETT. An additional piece of 1.25 x 30 cm was placed across the first piece as reinforcement; 2. A single 1.25 cm x 30 cm tape was attached to the upper border of the PVC face after wrapping twice around the ETT, and an additional 1.25 x 30 cm was attached to the lower border of the PVC face after wrapping twice around the ETT. Two additional 1.25 x 30 cm tapes were placed across the other tapes as reinforcement; 3. A single 2.5 x 30 cm tape was split in half along two-thirds of its longitudinal length to form a Y-shape. One of the two arms of the Y was wrapped twice around the ETT, while the other arm was attached along the upper border of the PVC face; 4. Similar to method 3, with an additional 2.5 x 30 cm tape wrapped around the ETT and attached to the lower border of the PVC face; 5. A single 5 x 30 cm tape was split into three equal parts along two-thirds of its longitudinal length. The outer two strips covered the upper and lower edges of the oval hole, and the middle strip wrapped twice around the ETT and then onto the PVC face; 6. Identical to method 1 except that 2.5 x 30 cm tapes were used; 7. Identical to method 2, except that 2.5 x 30 cm tapes were utilized. Taping methods are shown in Figures 1–5.

Tape Types

Five tape types that are commonly available in the operating rooms were used in the experiments: Leukopore "paper" (Biersdorf Inc., Norwalk, CT), Leukosilk "silk" (Biersdorf Inc.), Hy.tape (Hy.tape

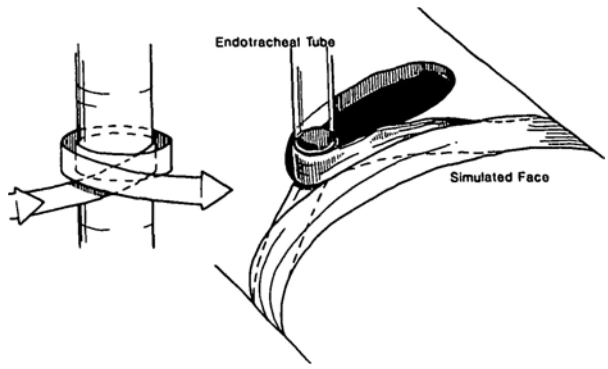

FIGURE 1 Taping methods 1 and 6. A single 30 cm long tape was attached to the upper "maxillary" border of the PVC face after wrapping twice around the ETT. An additional piece of 30 cm long tape was placed across the first piece as reinforcement. The width of the tape was 1.25 cm for method 1 and 2.5 cm for method 6.

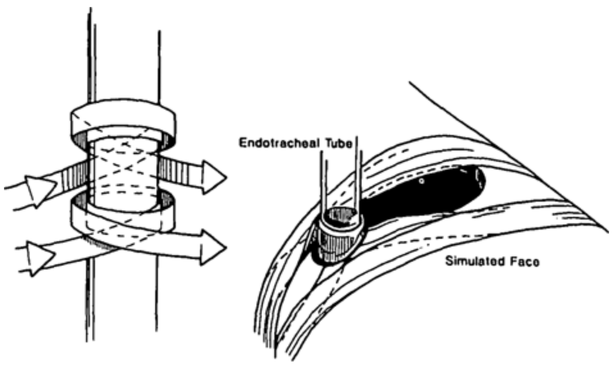

FIGURE 2 Taping methods 2 and 7. Two 30 cm long tapes were attached- one to the upper "maxillary" and the second to the lower "mandibular" border of the PVC face, after wrapping twice around the ETT. Two additional 30 cm long tapes were placed across the other tapes as reinforcement. The width of the tape was 1.25 cm for method 2 and 2.5 cm for method 7.

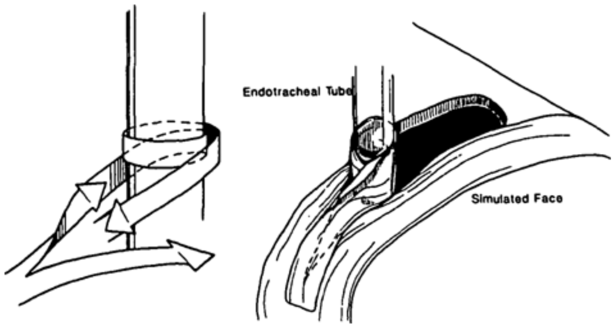

FIGURE 3 Taping method 3. A single 2.5 x 30 cm tape was split in half along two-thirds of its longitudinal length to form a Y-shape. One of the two arms of the Y was wrapped twice around the ETT, while the other arm was attached along the upper "maxillary" border of the PVC face.

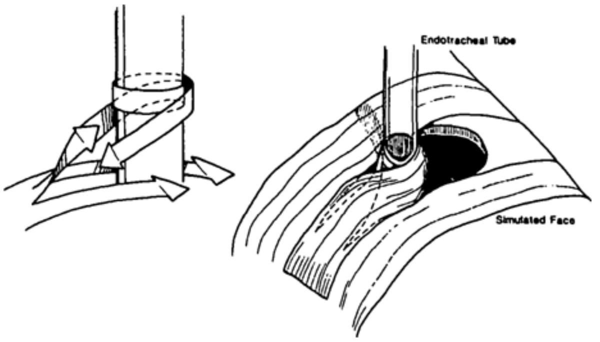

FIGURE 5 Taping method 5. A single 5 x 30 cm tape was split into three equal parts along two-thirds of its longitudinal length. The outer two strips covered the upper "maxillary" and lower "mandibular" borders of the oval hole, and the middle strip wrapped twice around the ETT and then onto the PVC face.

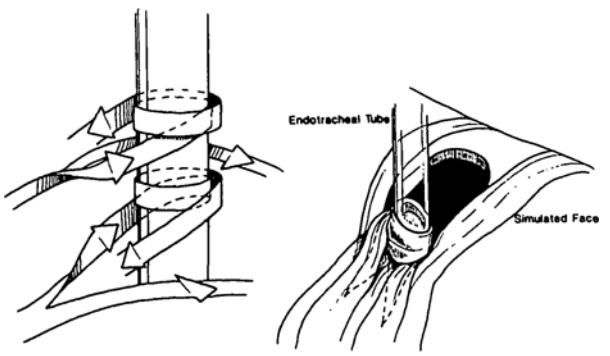

FIGURE 4 Taping method 4. Similar to method 3, with an additional 1.25 x 30 cm tape wrapped around the ETT and attached to the lower "mandibular" border of the PVC face.

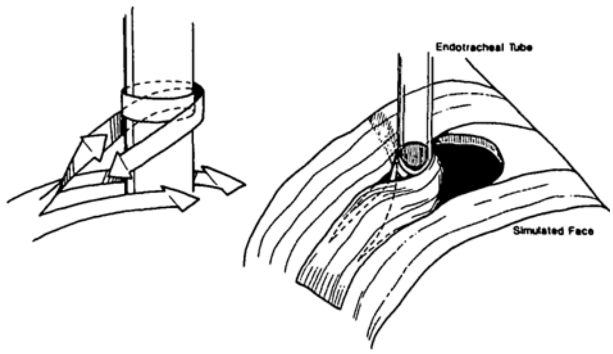

FIGURE 6 Experimental procedure. A constant pullout force was manually applied in a vertical, right, or left direction until the ETT was pulled out of the simulated face. A sharp decrease in recorded force signaled tube dislodgement.

Surgical Products Corp., New York, NY),Transpore "plastic" (3M Health Care, St Paul, MN), and Kendall Curity porous "cloth" (Kendall Healthcare Co., Mansfield, MA) tape.

Conditions of the Experiment

A piezo-electric force transducer (0-225 N range) was attached to the proximal end of the ETT where the breathing circuit would normally be attached. The transducer was connected to a graphic recorder. Standard weights were used to calibrate the system before each pullout test. The pullout test consisted of applying a manual force to pull out the secured ETT from the oval hole of the face model and recording the minimum force to pull out the tube on paper (Figure 6). The pullout force was generated by hand so as to simulate the clinical situation in which an ETT is pulled out accidentally with a large force of short duration. The mechanism by which the ETT was dislodged from the face model was recorded as tape fracture, tape tear, tape detachment, or a combination of these mechanisms. Fracture was defined as a break in the tape across its width, tear was a break in the tape along its long axis, and detachment was separation between the tape and PVC surface. Direction of the pullout force was either to the left (i.e., to the same side of the oval hole where the ETT was taped), to the right (i.e., to the opposite side of the oval hole where the ETT was taped), or in the vertical direction (i.e., perpendicular to the long axis of the PVC pile and oval hole). Between each pullout test, the PVC pipe and the ETT were cleansed and dried to eliminate any variation in adhesive qualities of the taping surfaces. A nail polish remover pad was used for this purpose (Professional Disposables Inc., Orangeburg, NY).

Statistical Methods
A randomized block design was used with each condition replicated 20 times. A total of 2100 pullout tests were performed (7 methods × 5 tapes × 3 directions × 20 replications). Randomization was with a table of random numbers. Pullout forces were compared among groups with ANOVA using the general linear model procedure (GLM, SAS software). Whenever the F ratio was significant, Tukey's test was then used. Mechanisms of dislodgement data were compared among groups with Chi Square analysis and Fisher's Exact test. A *P* value <0.05 was considered significant.

Results

Minimum forces to pull out ETTs were highest with method 7, intermediate with methods 2, 4 and 6, and lower with methods 1, 3 and 5 (Table I). Among the different tape types, minimum pull out forces were highest with Curity, intermediate with Hy.tape and Leukopore, and lowest with Transpore (Table I). Regardless of tape type, the most frequent mechanism of dislodgement was by tape fracture (Table II).

Dividing the tape along its longitudinal axis (methods 3, 4, and 5) resulted in lower minimal pullout forces whenever the pullout force was directed in the direction of attachment (Table III, $P < 0.05$ *vs* right and vertical direction). There were no directional differences with taping methods 1, 2, 6, and 7 (Table III). With methods 3, 4, and 5, mechanism of dislodgement was more likely due to tearing of the tape along its longitudinal axis (Table IV, $P < 0.05$ *vs* other four methods).

Discussion

Tracheal tubes are routinely used in anaesthesia to ensure airway patency and to provide a route for mechanical ventilation. Once placed, these tubes must

TABLE I Minimum Force to Dislodge Endotracheal Tubes: Comparison of Tape Types and Methods

Method	*N*	*Hy. tape*	*Curity*	*Leukosilk*	*Leukopore*	*Transpore*	*Row Mean ± SD*
1	300	47.6 ± 9.3 b,C,D	90.0 ± 30.2 a,C	51.8 ± 14.5 b,C	28.9 ± 8.6 c,C	19.8 ± 5.4 d,E	47.6 ± 29.1
2	300	81.6 ± 14.9 b,B	141.9 ± 50.1 a,B	91.7 ± 22.1 b,B	49.8 ± 13.7, c,B	35.1 ± 10.1 d,C	80.0 ± 45.6
3	300	39.2 ± 13.9 c,D	82.8 ± 51.3 a,C	58.7 ± 33.4 b,C	22.8 ± 11.8 d,C	19.4 ± 6.9 d,E	44.6 ± 37.1
4	300	82.1 ± 25.9 b,B	152.4 ± 98.1 a,B	106.3 ± 49.4 b,B	48.2 ± 29.2 c,B	35.3 ± 13.0 c,C	84.9 ± 66.9
5	300	51.0 ± 19.5 c,C	97.6 ± 47.5 a,C	68.2 ± 31.0 b,C	20.1 ± 10.3 d,C	26.4 ± 8.9 d,D	52.6 ± 39.4
6	300	90.0 ± 14.9 b,B	135.5 ± 33.2 a,B	94.0 ± 21.8 b,B	55.6 ± 17.1 c,B	41.4 ± 10.1 d,B	83.3 ± 39.0
7	300	151.8 ± 24.6 c,A	241.6 ± 56.7 a,A	180.8 ± 39.2 b,A	105.2 ± 22.4 d,A	82.2 ± 18.2 E,A	152.3 ± 66.5*
Mean ± SD		77.6 ± 33.9	134.5 ± 75.4†	93.0 ± 51.4	47.2 ± 32.2	37.1 ± 22.8	

Mean ± SD (newtons)
Means with same letter (lowercase) are not different ($P > 0.05$) when comparing tapes for a given method.
Means with same letter (uppercase) are not different ($P > 0.05$) when comparing methods for a given tape.
* Method 7 different from other methods ($P < 0.05$).
† Curity tape different from other tapes ($P < 0.05$).

TABLE II Mechanism of Dislodgement According to Tape Type

Tape	*DETACH*	*FRAC*	*FRAC-TEAR*	*FRAC-SEPA*	*TEAR*	*TEAR-SEPA*	*SEPA*	*TOTAL*
Curity	2	270	10	71	61	2	4	420
Hy. tape	0	325	46	33	16	0	0	420
Transpore	0	348	19	4	48	0	1	420
Leukopore	0	365	3	13	36	0	3	420
Leukosilk	0	305	11	43	61	0	0	420
Total	2	1613*	89	164	222	2	8	2100

Data are number of occurrences
Abbreviations:
DETACH is detachment of ETT at the proximal end.
FRAC is break in the tape across the width.
FRAC-TEAR is a combination of break in the tape across the width and tear.
FRAC-SEPA is a combination of break in the tape across the width and separation between tape and PVC face.
TEAR is a tear in the tape (longitudinal).
TEAR-SEPA is a tear in the tape (longitudinal) and separation between the PVC face and tape.
SEPA is separation between the PVC face and tape.
* $P < 0.05$ *vs* other mechanisms.

be immobilized and stabilized to prevent unwanted motion of the ETT which could result in accidental extubation or malposition.[3] Although a variety of methods have been developed to secure the ETT such as maxillofacial prosthetic appliances, intraoral wire stabilization, and Velcro strap devices,[4] these methods are more often used in the ICU and burn settings, and most anaesthetists still secure the ETT to the patient's face using tape. The study demonstrated that method 7, which consisted of taping the ETT in a circumferential fashion to both the upper and lower portions of the simulated mouth opening and reinforcing these tapes with two strips applied longitudinally across the borders of the mouth opening, resisted pullout to a greater extent than did all other methods. The study also demonstrated that ETTs secured with Curity tape resisted pullout to a greater extent, and when Curity tape was combined with method 7, minimum forces to dislodge the ETT were higher than with any other taping method – tape type combination.

Before using the PVC model for the pull out test, a number of mannikin models used for teaching tracheal intubation skills were tested. However, despite the use of a variety of liquid adhesive resins such as benzoin and mastisol, the tapes adhered poorly to the mannikin face. Therefore, the PVC model was employed. There are limitations of the simulated PVC model. The face of a human differs from the simulated model in that the human face is a non-rigid structure that imparts considerable flexibility when subjected to stretching forces. Also, the contours and the precise shape of the model and the human face are considerably different. The face of the patient is not a dry, even, smooth surface, but has hairs, oils, and sometimes scars, saliva, and blood that may alter adhesiveness of the applied tape to secure the ETT. Despite these limitations, the PVC model does provide a rigid structure than can be used indefinitely for a very large number of pullout tests. As well, the PVC model has been used previously to evaluate different methods of

TABLE III Minimum Force for Dislodgement of Endotracheal Tubes According to Direction of Pullout

Method	*N*	*Right*	*Vertical*	*Left*
1	100	41.3 ± 23.9	52.5 ± 31.7	49.0 ± 30.3
2	100	74.7 ± 40.8	93.4 ± 53.2	71.9 ± 38.9
3	100	60.4 ± 44.0	53.4 ± 34.4	19.8 ± 9.40*
4	100	124.9 ± 81.4	94.9 ± 49.1	34.8 ± 15.8*
5	100	68.7 ± 43.4	62.5 ± 39.3	26.7 ± 15.0*
6	100	75.3 ± 33.1	86.7 ± 38.1	88.0 ± 44.0
7	100	148.1 ± 63.1	166.6 ± 72.1	142.3 ± 61.9

Mean ± SD (newtons)
* $P < 0.05$ *vs* right and vertical for a given method.

TABLE IV Mechanism of Dislodgement According to Taping Method

Tape	*DETACH*	*FRAC*	*FRAC-TEAR*	*FRAC-SEPA*	*TEAR**	*TEAR-SEPA*	*SEPA*	*TOTAL*
1	0	249	10	30	7	0	4	300
2	0	260	15	20	3	1	1	300
3	0	217	10	2	71	0	0	300
4	0	213	16	2	69	0	0	300
5	0	225	2	2	71	0	0	300
6	0	196	23	76	1	1	3	300
7	2	253	13	32	0	0	0	300

Data are number of occurrences
Abbreviations:
DETACH is detachment of ETT at the proximal end.
FRAC is break in the tape across the width.
FRAC-TEAR is a combination of break in the tape across the width and tear.
FRAC-SEPA is a combination of break in the tape across the width and separation between tape and PVC surface.
TEAR is a tear in the tape (longitudinal).
TEAR-SEPA is a tear in the tape (longitudinal) and separation between the PVC and tape.
SEPA is separation between the PVC face and tape.
* $P < 0.05$ for methods 3, 4 and 5 *vs* other methods.

securing intravenous catheters with tape,[2] and has yielded data that were comparable with those obtained from human volunteers.[5] For example, the minimal pull out forces for catheters secured with Curity tape were 63 N in the PVC model *vs* 52 N in human volunteers.[5] Corresponding values for Transpore tape were also quite similar, 55 N *vs* 44 N.[5] Moreover, there were no differences in mechanism of dislodgement of the taped *iv* catheters between the PVC model and the human volunteers.[5]

Splitting the tape along its longitudinal axis before securing the ETT, as in methods 3, 4, and 5 reduced the force required to dislodge the ETT, especially when the pullout force was directed leftward. As well, with methods 3, 4, and 5, tearing was a frequent mechanism by which the ETT was dislodged from the face model, indicating that splitting weakens the structural integrity of the tape and thereby reduces the ability of the secured ETT to resist accidental dislodgement. Method 2 differed from method 7 only by the use of 2.5 cm instead of 1.25 cm tapes. Use of the thicker tape increased the minimum pull out force nearly two-fold, and should therefore be considered whenever the lower (mandibular) and upper (maxillary) portions of the mouth opening safely permits the placement of this width of tape. Application of adhesive liquid resins such as mastisol or benzoin would be expected to increase the adherence of tape to the patient's skin and reduce the likelihood of dislodgement, as has been shown for Leukopor and Curity tape previously.[5]

The present study measured the minimum force to pull out ETTs using a variety of tapes with differing adhesive qualities and differing tensile strength. For Curity tape, manufacturer reported tensile strength at break was 225 N/2.5 cm, about 10 times that of the lowest tensile strength tape tested, Transpore (25 N/2.5 cm). Corresponding values for Leukosilk, Hy.tape, and Leukopor were 99, 52, and 45 N/2.5 cm, respectively. Thus, tapes with higher tensile breaking strength would be expected to resist dislodgement to a greater extent in the clinical setting. This trend was observed in the present study. However, despite the nearly ten – fold difference in the tensile strength of Curity over Transpore, there was approximately a three – fold difference between these tapes in terms of minimum force to dislodge the ETTs. Therefore, extrapolation of manufacturer bench tests to the clinical setting may be misleading.

Hand generation of pull out force was used in the present study instead of laboratory test machines because many machines are not capable of rapidly increasing the applied force so as to simulate a sudden jerk or tug, and spring loaded testing devices would increase the pullout force too rapidly. This type of force was chosen to simulate the force versus time profile that might be encountered in clinical situations in which an ETT is pulled or tugged on in a jerky fashion, or if the patient intentionally or accidentally attempted to remove the ETT with a large force of short duration. The main disadvantage of manual force generation is larger variation in the measured forces. The increased variability can be overcome by increasing the number of replications of each experimental condition, as was done in the present study.

It should be noted that the study evaluated forces generated along the right, left and vertical directions. Minimal forces to pull out the ETTs were lower whenever the force was applied in the leftward direction, especially when the tape had been split as in methods 3, 4, and 5. These different directions were used because accidental dislodgement may occur after sudden pulls along several axes in a variety of directions depending on the clinical situation – e.g., when turning the patient's head during head and neck surgery, during patient positioning (e.g., supine to lateral or supine to prone), when transferring the orally intubated patient to or from the operating room table and during patient transport. Other factors that are important in reducing the risk of accidental dislodgement include proper support of breathing circuit tubing, adequate level of anaesthesia during movements of the head and neck to prevent coughing and gagging, and removal of excessive oral secretions which could reduce the adhesiveness of tape to skin. The importance of ensuring a clean, dry, skin surface prior to taping, and vigilance, especially during patient positioning, transfer and transport, cannot be overemphasized.

In summary, the data suggest that there are important differences in taping methods and tape types in preventing accidental ETT dislodgement. ETTs secured and reinforced with Curity tape in a circumferential fashion along the upper and lower borders of the mouth opening appeared to offer the highest resistance to dislodgement in the simulated model. Splitting the tape along its longitudinal length reduced the minimum dislodgement forces and increased the likelihood of dislodgement by tearing.

Acknowledgments

The authors are greatly indebted to Joan Hagen for assistance with data analysis and Fran Hall for manuscript preparation.

References

1 *Christie JM, Dethlefsen M, Cane RD.* Unplanned endotracheal extubation in the intensive care unit. J Clin Anesth 1996; 8: 289–93.

2 *Patel N, Smith CE, Pinchak AC, Hancock DE.* Evaluation of different methods of securing intravenous catheters: measurement of forces during simulated accidental pullout. Can J Anaesth 1995; 42: 504–10.

3 *Levy H, Griego L.* A comparative study of oral endotracheal tube securing methods. Chest 1993; 104: 1537–40.

4 *Donlon WC, Truta MP, Hilt DM.* A simple method of nasoendotracheal tube fixation. Ann Plast Surg 1989; 23: 461–2.

5 *Patel N, Smith CE, Pinchak AC, Hancock DE.* The influence of tape type and of skin preparation on the force required to dislodge angiocatheters. Can J Anaesth 1994; 41: 738–41.