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Comparison of Commercial and Non-Commercial Endotracheal Tube Securing Devices

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ABSTRACT

INTRODUCTION: Tracheal intubation is used to establish a secure airway in patients who require mechanical ventilation. Unexpected extubation can have serious complications including airway trauma and death. Various methods and devices have been developed to maintain endotracheal tube (ETT) security. Associated complications include pressure ulcers due to decreased tissue perfusion. Device consideration includes ease of use, rapid application, and low exerted pressure around the airway.

METHODS: Sixteen ETT holders were evaluated under a series of simulated clinical conditions. ETT security was tested by measuring distance displaced after a tug. Nine out of the 16 devices could be evaluated for speed of moving the ETT to the opposite side of the mouth. Sensors located on a mannequin measured applied forces when the head was rotated vertically or horizontally. Data were analyzed using multivariate ANOVA with $p < 0.05$ as significant.

RESULTS: Median displacement of the ETT by the Tug test was 0 cm, IQR 0.0 - 0.10 cm, $p < 0.0001$. The mean time to move the ETT from one side of the mouth to the other ranged from 1.25 ± 0.2 s to 34.4 ± 3.4 s, $p < 0.0001$.

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Forces applied to the face with a vertical head lift ranged < 0.2 N to a maximum of 3.52 N, $p < 0.0001$. Forces applied to the face with a horizontal rotation ranged < 0.2 N to 3.52 N, $p < 0.0001$. Commercial devices produced greater force than non-commercial.

CONCLUSION: Non-commercial airway holders exert less force onto the patient's face than commercial devices. Airway stability is affected by the type of securing device.Many of the commercial holders allow for a rapid, but secure movement of the artificial airway from one side of the mouth to the other.

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INTRODUCTION:

The purpose of an artificial airway is to relieve upper airway obstruction, facilitate suctioning, allow effective ventilation and prevent aspiration. Unintended removal or dislodgement of the endotracheal tube (ETT) can have harmful effects ranging from localized trauma, and aspiration of oral/gastric secretions, to death as a result of a compromised airway[1] Alternatively, extended pressure from securing the ETT on the surrounding tissue can lead to pressure sores and mucosal damage. This is a direct result of the securing device causing pressure points decreasing local tissue perfusion[2]. In addition, ETT can be inadvertently advanced to the carina or into a mainstem bronchus.

The Joint Commission has made pressure ulcer prevention a national patient safety goal (http://www.jointcommission.org/, *Accessed May 2, 2012)*. Pressure ulcers can range from discomfort to disfiguring sores. Current American Heart Association (AHA) guidelines suggest that ETT should be secured with "tape or a commercial device."[3] There are a myriad of devices that are designed to secure the ETT. All of these devices and techniques have similar goals: to keep the artificial airway secure, and to keep the patient safe by maintaining an intact airway and minimizing the chance of an unplanned extubation.

When considering the type of device to secure the airway: ease of use, efficiency in keeping the airway secure, and the ability to reposition the ETT to prevent pressure ulcer formation should be considered. Methods of securing an ETT vary from straps of tape or cotton string, to mechanical devices with integrated securing and movement mechanisms. The purpose of this study was to evaluate a wide array of commercially

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available devices and traditional ETT securing techniques under simulated clinical conditions. The conditions tested were designed to evaluate the ability of the holder to keep the ETT in place, the rapidity of relocating the ETT from one side of the mouth to the other, and finally how much force is transmitted to surrounding areas covered by the device as the head is moved.

METHODS

Sixteen unique ETT holding devices or securing methods were subjected to four separate tests to evaluate performance in simulated daily activities of the mechanically ventilated acutely ill patient. The tests performed were, (1) static tug test, subjecting the ETT secured by one of the holders to a momentary force pulling on the ETT in an attempt to remove the ETT from the airway; (2) ETT movement, determination of the time required to move an ETT from one side of the mouth to the opposite side of the mouth; (3) vertical movement, determination of the pressure applied by the device to the face and neck during simulated raising and lowering of the head 30 degrees; and (4) horizontal movement, determination of the pressure applied by the device to the face and neck during simulated turning of the head from side to side in a 70 degree arc. All commercial devices were supplied by the manufacturer. (Table 1). Some of the holders evaluated incorporated a band of material that wrapped around the back of the neck for stability. For those holders, the tension along the band was set to allow two fingers to pass snugly between the band and the surface of the mannequin head parallel to the head.

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Airway Model

An anatomically correct adult intubation model (Airway Larry #25000033 Laerdal, Wappingers Falls, NY) was used to simulate the head and upper airway. An 8.0 mm internal diameter (ID) ETT (Covidien Mallinckrodt Hi-LO) was inserted into the trachea and secured by each of the 16 devices/methods evaluated. The cuff was inflated to 25 cm H_2O establishing a minimal leak.[4] Cuff pressure was checked and re-established immediately before each experimental trial.

Static Tug Test:

The intubation mannequin was orally intubated at the beginning of each series of evaluations with every device. Prior to each intubation, the upper airway was lubricated with silicone spray (Laerdal Airway Lubricant, Cat No. 25-20-90, Laerdal Wappingers Falls, NY) to simulate lubrication of the airway with secretions and allow for a greater freedom of movement than was available with dry plastic-on-plastic.

The ETTs were secured with each of the 16 devices/methods. After securing the ETT, the cuff was slowly inflated to a pressure of 25 cm H_2O monitored by a pressure manometer with an incorporated luer-lok connection (Instrumentation Industries BE 148-7, Bethel Park, PA). Using modified test apparatus as previously described,[5, 6] the ETT was connected to a pre-stressed 80-lb test nylon line (Mason Tackle, Otisville, MI). The opposite end of the line was threaded through a pulley and attached to a 578 g weight. The resulting angle formed between the pulley and the intubation head was 30 degrees equal to the head of bed elevation angle suggested in the ventilator associated pneumonia

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(VAP) bundles[7] (Figure 1). A reference mark was made on the side of the ETT denoting tooth position at the beginning of the test.

During a pilot test for this study, the weight was applied without a tug and tube movement recorded. No discernable movement occurred. To prevent bias toward adhesives, the face of the mannequin was covered with a new sheet of plastic film (Blenderm, 3M) at the start of testing on each new device. This was to prevent any potential interaction between the adhesive and residual cleaner, as well as providing a better surface for adherence than the outer covering of the intubation head.

The weight was then dropped from a height of 98 cm and allowed to free fall before stopping abruptly at 16 cm above the tabletop producing a jolt of approximately 5.7 Newtons on the ETT in the direction away from the patient as an attempt to extubate the model. The distance the ETT moved was then recorded. This process was repeated 5 drops per run, and 5 runs per series, using 4 devices per evaluation resulting in a possible 100 drops for each holder evaluated. Following the fifth drop and measurement, the cuff was deflated, the ETT repositioned, and the securing method refastened. At the end of the fifth run in each series, the securing device was removed; the ETT was placed back into the starting position, secured with a new device from the same manufacture, and the complete series of runs repeated. A new, previously unused device was used during each series for each securing technique.

If during testing, the ETT became dislodged, or moved > 5 cm it was considered an extubation and testing was stopped for that cycle (This distance is considerably greater than the 20 mm suggested by others.[6]). The ETT was then repositioned and refastened with a new device/method and a complete series of drops repeated with a new

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device/method. If the ETT was dislodged completely again, the series with the greatest number of measurements would be used for analysis. When the distance moved was less than 5 cm, the distance moved was recorded, the initial tube position re-established and testing continued.

Side to Side ETT Movement:

For this portion of the evaluation, six of these devices were excluded due to a common design feature which prevented lateral tube movement; an integrated bite block. Another device was excluded because it was an optional head strap that would have no impact on lateral tube position. The specific devices excluded from this evaluation were: AMBU (Velcro), AMBU (silicone strap), Thomas tube holder (Laerdal), Precision Medical, Portex Quickstrap, Teleflex, and Marpac 320 with headstrap. The nine remaining devices/methods were evaluated for speed in moving the ETT from one corner of the mouth to other. For the commercial devices, the manufacturer's instructions were followed. With the non commercial methods the knots evaluated were tied as described by a web-based knot reference (http://www.animatedknots.com/, *Accessed May 2, 2012*). Prior to testing the investigator practiced each knot until it could be rapidly tied without assistance.

At the start of the testing, the ETT was secured adjacent to one corner of the mannequin's mouth. The investigator moving the airway would signal to the timing investigator when to start the stopwatch. When the airway was repositioned, the repositioning investigator would signal when to cease timing. This action was repeated a

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total of 10 times for each method. To limit variation in technique the same person (DF) performed all repositioning and the same person kept time (JK) with all devices and techniques.

If there was a problem during the movement, or either investigator felt that conditions were not optimal, or the results were considered to be outside of 1 standard deviation when compared with the other trials of the same device/method, the trial was discarded and repeated using the same device/method.

Rotating Head Study:

The intubation head was removed from the stock torso and placed on a computer-controlled platform that has independent motion on 2 axes (Figure 2). Digital encoders were attached to each drive motor to provide spatial reference for the axis of rotation. Control of each motor was governed via a graphical interface (Labview, National Instruments). Five force sensing resistors (FSR; Interlink Electronics, Camarillo, CA) were placed around the mouth and nose (Figure 3). An additional sensor was placed on the back of the neck. Sensor data from the FSRs were recorded as a voltage every 100 milliseconds using an analog to digital converter and output as a text file. During analysis, the voltage was converted to Newtons (N) of force based upon the separate calibration curves for each sensor which were developed before any measurements.

The upper airway was lubricated with silicone spray and the head was orally intubated in the same fashion as previously described. The ETT was secured using a new device/method for each trial. The secured ETT was then connected to a ventilator circuit (Hudson RCI model #780-32) supported by a cross arm.

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The vertical elevation test was carried out by having the head lift from 3 to 30 degrees simulating the head being raised from a flat to a semi-recumbent position at a rate of 12 rotations every minute. For the horizontal rotational testing the head moved in a 70 degree arc at a rate of 5 rotations every minute. Run time for each axis was 10 minutes in order to allow for stabilization of the system. Due to the design features of each ETT fixation device/method, the FSRs were moved to be under potential high pressure points as determined by the investigators during pilot studies. Specific sensor locations for each device are in the supplementary material. (Supplementary Figure 1)

The system was started with the head in the "neutral" position, 0 degrees elevation and 0 degrees rotation from midline. During this startup, the system would recalibrate position. Testing occurred only with one axis movement at any time. Data was recorded at a rate of 100 ms, which included all sensor voltages, angular position, and time. This recording was saved into a text file for later analysis.

Data Analysis:

Data was checked for normality using the Shapiro-Wilk test. All normally distributed data were expressed as mean plus or minus standard deviation. Nonparametric data was analyzed using multivariate ANOVA with $p < 0.05$. *Post-hoc* analysis was performed using the Tukey HSD test. All data analysis was performed using R statistical software, (version 3.0.1, R Project for Statistical Computing).

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Static Tug Test

Distance moved was collected for each of the 100 trials per device/technique. Tube displacement > 5 cm was considered extubation; the remaining successful drops for the holder were evaluated.

Side to Side ETT Movement

The time needed to move the ETT was compared using a one-way ANOVA with Tukey HSD between devices and within each device.

Rotating Head Study

The system was allowed to stabilize one minute. The next 5 complete cycles were collected and the voltage readings of the FSRs were converted into Newtons based from calibration curves specific for each of the six sensors. When any device or technique did not have a portion go around the neck of the intubation head, or touch a portion of the face such as the chin, those sensors were not included in the analysis.

With the vertical axis movement, data was collected at 3, 15, and 30 degree positions. The horizontal axis movement data was collected at -35, 0, and 35 degree positions. Five data points at each of the three angles were selected for each device. Since five of the same type of ETT holders were used during each evaluation a total of 25 data points for each angle for each device were analyzed. If 5 data points at a specific angle were not available, the closest data point from the preceding or following angle were recorded to bring the total to 5. We used repeated measures multivariate ANOVA to compare the effects of device, angle of rotation/elevation, type of device; commercial

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or non-commercial, and the trial run between devices as well as comparing each device to itself. For all evaluation a $p < 0.05$ was considered significant.

Results:

Static Tug Test

There were 1600 potential observations. During testing 17 complete dislodgements were noted (2 with the Portex Quickstrap, 15 with Precision Medical #PM 1110). To compensate for the stretching of the new material, the first series of five drops for each holder was removed (Run Series 1). Two of the 17 extubations occurred in this series, both for the PM 1110 device and were omitted from analysis. This resulted in a total of 1265/1280 observations. The median displacement for this group was 0.00 cm, IQR 0.0 -0.10 cm. The holders with the least movement (median, IQR) were Anchor Fast (0.0 cm; 0.0 – 0.00 cm), Hy Tape (0.0 cm, 0.0 – 0.00 cm), and the modified Lillihei method (0.0, 0.0 – 0.00 cm), and the holder with the greatest displacement was the Precision Medical 0.2 cm, IQR 0 - 1.1 cm; $p < 0.0001$, (Table 2). The displacement distance (median, IQR) for both commercial and non-commercial devices were the same (0 cm, 0.0 – 0.10 cm), but all of the extubations that occurred during testing happened with the commercial devices and none occurred with the non-commercial devices, $p = 0.0009$. Table 2.

Tube Repositioning Study

An average of 13.8 $\pm$ 12.3 seconds was required to move the ETT for the 9 devices/methods evaluated. The shortest period of time was documented for the Marpac

320 (0.82 ± 0.14 s), and Hollister Anchor Fast (1.25 ± 0.20 s). The difference between these two devices was not significant, $p = 0.9999$. The two slowest methods for movement were Hy Tape (32.0 ± 4 s), and the modified Lillihei method (34.4 ± 3.44 s), again, the differences between these two devices was not significant, $p = 0.51$ (Table 3). Commercially available devices took less time to move the ETT when compared with non-commercial techniques, (5.58 ± 6.57 s vs. 17.91 ± 12.48 s respectively) $p < 0.0001$.

Rotational Head Studies

There were 1200 observations for sensors 1 through 4. Both sensors 5 and 6 had 1050 observations each. Sensor 5 was the chin placement, and sensor 6 was the back of the neck. This is because three holders had designs which did not cover those sensor areas on the mannequin (Hy Tape – no sensor 5 or 6, Lillihei method – no sensor 5, Modified Lillihei method – no sensor 5 or 6), see Figure 3.

Vertical Head Lift

Forces measured varied among each sensor for all of the ETT holders, $p < 0.0001$. The greatest force recorded at any time was 3.52 N (AMBU # 320264040) at sensor 1. The least force recorded was < 0.2 N; this measured force was beyond the resolution for the sensors so a more precise measurement is unavailable. Grouping the forces into the three angles (3, 15, and 30 degrees), force readings at individual sensors varied among device, 1 through 4 $p < 0.0001$, sensor 6, $p = 0.002$ and sensor 5, $p = 0.07$. Summary force readings mean ± SD at each sensor for each device are shown in Supplementary

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Tables 1a-c. Commercial devices exerted more force than non-commercial methods; all sensors $p < 0.0001$ see Figure 4.

When the individual devices were analyzed, the AMBU holder # 320264040, the Marpac 320 with headgear, Cow Hitch, Lillihei method and Teleflex #1065 did not show any difference between forces measured among the sensors.

Horizontal Head Turning

Force readings were different for each sensor with every device, $p < 0.0001$. The greatest force recorded at any time was 3.40 N (AMBU # 320264040) at sensor 1. The least force recorded was < 0.2 N; this measured force was beyond the resolution for the sensors so a more precise measurement is unavailable. Grouping the data into the 3 angles (-35, 0, and 35 degrees), the forces measured for all devices showed wide variation, $p < 0.0001$ with the exception of the Lillihei method $p = 0.06826$. Summary force readings, mean $\pm$ SD are listed in Supplementary Tables 2a-c.

Commercially available devices exerted more pressure at all sensors than non-commercial devices with the exception of sensor 4. It registered higher forces with non-commercial device than commercial devices, Figure 5.

Discussion:

This is the most comprehensive study to date, examining a large variety of ETT securing devices under four different simulated clinical conditions. No single device design performed well in all of the evaluations.

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The force exerted on the patient's face by many of the commercial securing devices may result in discomfort and the formation of pressure ulcers. Non-commercial techniques use materials (tape, string) that are more form-fitting to the patient's face and therefore do not have the same pressure point issues as seen with the commercial devices.

Barnason [8] looked prospectively, at the impact of two securing techniques on patient comfort and skin integrity. The techniques used to secure the airway were the Lillihei method and cotton twill with a Cow Hitch knot. Pressure on the patient's face was based more on descriptive findings rather than quantifiable measurements. Their conclusion was both techniques were equally effective in preventing oral mucosal breakdown which is consistent with our findings.

Resistance to movement after the ETT has been subjected to an unplanned tugging motion is crucial to the function of any ETT holder. In general the non-commercial devices, because of variation in gripping ability did not perform as well as the commercial devices.

Two separate studies [5, 9] used a similar technique as we did for creating dynamic torque on the ETT by dropping a weight via a pulley. Murdoch and Hollgate's design was for the force generated to be perpendicular to the intubation mannequin. They considered a movement of the ETT $\geq$ 20 mm a major displacement. The two techniques evaluated were the Laerdal Thomas Tube Holder and twill tape tied with a reef (square) knot. During testing, they noted that in 61% of the trials the tape allowed ETT movement of $\geq$ 20 mm whereas none of the trials with the Laerdal device met failure criteria. An explanation for this discrepancy may be that the reef knot was a poor choice and that a better holding knot would have been the Rolling Hitch.

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Lovett used a PVC pipe as an intubation model and then saturated the holders once applied with saline to simulate oral secretions[5]. They measured the actual force generated when dropping 2.5, 5, and 10 lb weights and measuring the distance the ETT moved after 6 and 15 drops. This method provided the average distance moved after a sequence of drops rather than the effects of each drop. Although there was a difference in models, PVC pipe vs. intubation mannequin the performance was similar to what we experienced for the three holders that were common for both studies (Lillihei, Precision Medical, and Thomas Tube Holder)

The overall poorest performer during the static tug test, Precision Medical, utilized a thin securing strap which stretched significantly. It is the elasticity of the strap that allowed for a large displacement of the ETT. This finding is similar to that by Carlson.[9] In fact, the strap was so compliant; it was difficult to secure the airway with only a "two-finger tight" assessment, two fingers snugly fitting between the face of the mannequin and the securing strap. This issue was evident to some degree with other devices employing a similar design where there was too much material requiring multiple layers of wrapping, or in extreme conditions, tightening beyond the recommended two-finger test. Devices in this class were the AMBU ETT holder with blue silicone strap, Smiths-Portex Quickstrap, and Dale Stabilok.

Several manufacturers secured the ETT, by compressing the ETT between a clamp or screw. These mechanisms had an influence on the cross-sectional shape of the airway. This distortion may have an influence on airway resistance, but it was not within the scope of this investigation to measure airway resistance.

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Several commercial devices are designed to allow for quick tube position relocation, and in fact outperformed non-commercial devices. A common design feature for the commercially-prepared holders was a track where the ETT could be guided from one point to another. The non-commercial holders all required disassembly and reassembly of the securing technique; two techniques (modified Lillihei method, and Hy Tape) required a completely new holder to be fashioned after moving the airway. This resulted in the airway being unsecured and susceptible to displacement, either by the practitioner, or by the patient.

Causes of unplanned extubation

There are two classifications of unplanned extubation (UEX): patient initiated, and practitioner initiated. Both categories of UEX place the patient at some risk depending upon their clinical status. It has been one of the primary goals of ETT fixation to secure the ETT in a manner where the airway is unlikely to become dislodged, yet flexible enough not to cause damage to surrounding tissue. In one multicenter study examining UEX, the lack of a "strong" fixation device was found to be one of the risk factors identified.[10]

UEX can lead to co-morbidity including increased ventilator days, and increased mortality [10, 11]. UEX has been associated with an increased likelihood of transfer to chronic care facilities.[11] Among the factors affecting transfer are skin integrity, complexity of the ETT securing device, oral care, speed of application of the device to the ETT, and patient comfort. No one device can address every factor, nor is it possible to test for every contingency.

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Ability to relocate the ETT Position

Devices with an integrated bite block prevent the ETT from being repositioned which may lead to pressure ulcers in the mouth and surrounding tissue. Kuhn reported on the development of a necrotic region on the tongue of a patient after only eight hours of intubation.[12] The bite block incorporated with some devices can also interfere with providing adequate oral hygiene by preventing access to the oral cavity. There is at least one report of an added bite block interfering with cuff function.[13]

Limitations:

There are several limitations to this study. First, this was a bench study and the surface of the mannequin may have behaved differently with the various adhesives used by some of the manufacturers than natural skin. This property was standardized with the application of the Blenderm product whenever the adhesive properties were being stressed during the static tug. Nonetheless, the skin of the intubation head does not have the same tensile qualities of real skin and thus may have impacted the pressure readings measured when securing the ETT.

Secondly, all readings were done at ambient temperature (~ 68^{o} F) without oral secretions saturating the securing devices/methods. Previous studies examined the securing properties of various devices both in simulation and *in*-vitro, identified oral secretions as factors affecting function.[5, 8, 9, 14] These studies were either of small sample size, or anecdotal discussions of various ETT holders. In the study by Carlson[9], extubation force was determined using fresh, < 24 hour old refrigerated cadavers and

actual force was measured using a strain gauge. Studies by both Arrott and Barnason were either descriptive or observational in nature.[8, 15] In clinical practice, there is no opportunity to pre-stress the neck strap as occurred during the static tug test, so actual ETT displacement distances may be greater than reported here.

Thirdly, during the tube movement, the goal was to move the airway as quickly as possible. It is likely that under clinical circumstances, concern for the safety of the patient would have a slowing effect on tube movement. As a result, timing was most likely shorter than during actual clinical conditions.

Fourthly, the movement of the ETT further into the airway, i.e. a mainstem bronchus, was not evaluated in this study. This is an important issue and should be considered for future studies.

Finally, this study was not designed to measure the convenience factor in application of the devices, which can have an impact on choice of device/method.

Conclusion:

Conclusions for this study are as follows: 1) Non-commercial airway holders exert less force onto the patient's face than commercial devices; 2) Airway stability is affected by the type of securing device selected; and 3) many of the commercial securing devices allow for a rapid, but secure movement of the artificial airway from one side of the mouth to the other. However, at this time there is no ideal device or method for securing ETT.

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Legends to Figures

Figure 1. Static Tug setup. The angle between the intubation head and the pulley was 30 degrees simulating a patient in the semi-fowler's position. The weight was dropped and allowed to fall freely until stopping abruptly causing a jolt.

Figure 2. Illustration of the mannequin setup for the vertical and horizontal movement evaluation. The platform uses gear motors and encoders to pivot the mannequin head in two dimensions. Control for the motors is via a LabView interface.

Figure 3. Sensor Placement for Rotating Head Study Numbers indicate sensor placement. Sensor 6 was on the back of neck for those holders that had a strap.

Figure 4. Graph of pooled forces measured during the vertical head lift at each sensor between commercial and non-commercial ETT holders.

Figure 5. Graph of pooled forces measured during the horizontal head rotation at each sensor between commercial and non-commercial ETT holders.

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Table 1: Devices/Techniques used

Commercial Methods

Device	Manufacturer
AMBU ET Tube Holder (blue strap) # 320264040	AMBU
AMBU ET Tube Holder (white strap) # 320264041	AMBU
Stabilock ETT Holder	Dale
Anchor Fast	Hollister
Thomas Endotracheal Tube Holder	Laerdal
Marpac 320	Marpac
Marpac 320 with optional headgear	Marpac
Quickstrap Endotracheal Tube Holder	Portex
Endotracheal Tube Holder # PM1110	Precision Medical
Cushioned Endotracheal Tube Holder #1065	Teleflex

Non-Commercial Methods

Device	Material Used
Clove Hitch	Cotton Twill
Cow Hitch	Cotton Twill
Rolling (Magnus) Hitch	Cotton Twill
Hy Tape	Hy Tape ¼ inch
Lillihei method using cloth tape	Covidien Cloth Tape
Modified Lillihei Method	Covidien Cloth Tape

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Table 2. Static Tug Results by Device

Holder	n	Median (cm)	Min (cm)	Max (cm)	IQR	Type
Hollister Anchor Fast	80	0.00	0.00	0.10	0 - 0.00	comm
Hy Tape	80	0.00	0.00	0.10	0 - 0.00	non
Modified Lillihei Method	80	0.00	0.00	0.10	0 - 0.00	non
Laerdal Thomas Tube Holder	80	0.00	0.00	0.20	0 - 0.10	comm
Lillihei Method	80	0.00	0.00	1.10	0 - 0.10	non
Marpac 320 with Headgear	80	0.00	0.00	0.50	0 - 0.10	comm
Rolling Hitch	80	0.00	0.00	0.30	0 - 0.10	non
Teleflex # 1065	80	0.00	0.00	0.30	0 - 0.10	comm
Portex Quickstrap	78	0.00	0.00	0.50	0 - 0.20	comm
Clove Hitch	80	0.10	0.00	1.00	0 - 0.10	non
AMBU ET Tube Holder (white strap) # 320264041	80	0.10	0.00	0.80	0 - 0.12	comm
AMBU ET Tube Holder (blue strap) # 320264040	80	0.10	0.00	0.80	0 - 0.20	comm
Cow Hitch	80	0.10	0.00	1.40	0 - 0.20	non
Dale Stabilock	80	0.10	0.00	1.10	0 - 0.20	comm
Precision Medical # PM1110	67	0.20	0.00	3.50	0 - 1.05	comm
Marpac 320	80	0.20	0.00	1.00	0.1 - 0.30	comm

Median distance displaced for static tug test. n less than 80 indicates number of complete extubations. All distances are in cm. Comm = commercially prepared device, non = non-commercial device.

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Table 3. Time needed to move the ETT by Device

Holder	Mean (sec)	SD (sec)
Marpac 320	0.82	0.14
Hollister Anchor Fast	1.25	0.20
Cow Hitch	2.79	0.34
Clove Hitch	4.21	0.54
Rolling Hitch	7.48	1.16
Bow *	8.48	0.83
Dale Stabilock	14.67	1.10
Lillihei Method	20.84	5.51
Hy Tape	32.02	4.00
Modified Lillihei Method	34.42	3.44

Mean $\pm$ SD time is seconds to move the ETT from one side of the mouth to the other.

* See text for description of knots.

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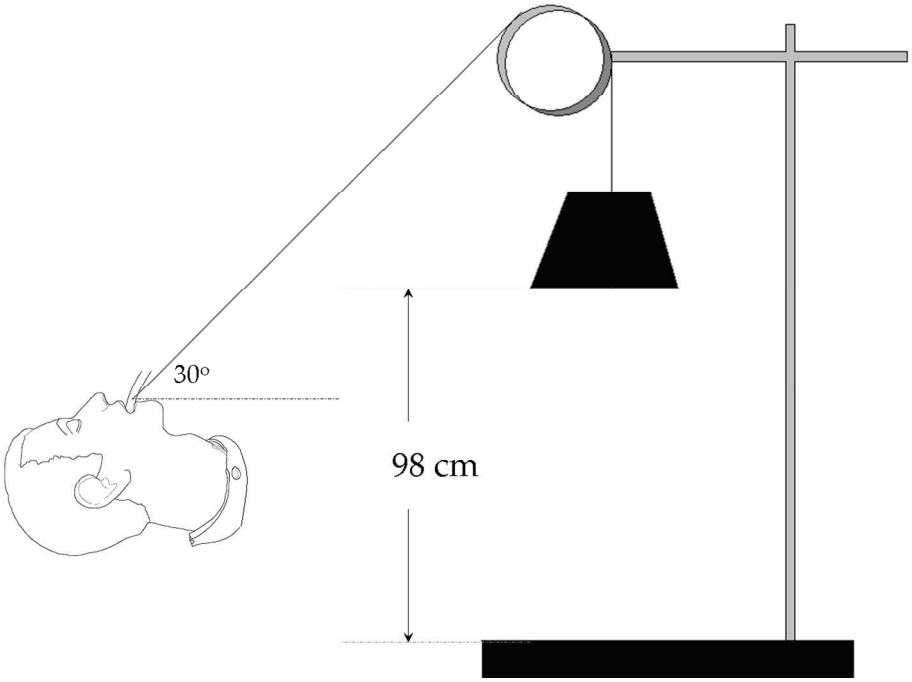

383x260mm (96 x 96 DPI)

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302x148mm (96 x 96 DPI)

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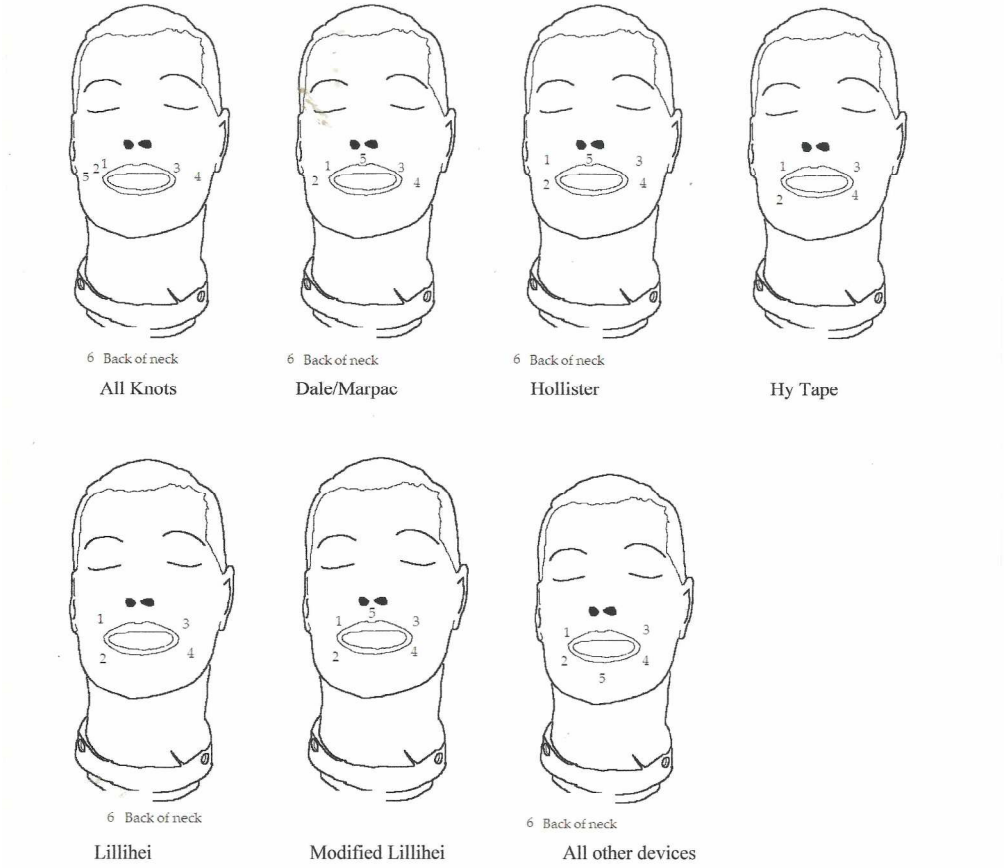

Figure 3.

216x230mm (300 x 300 DPI)

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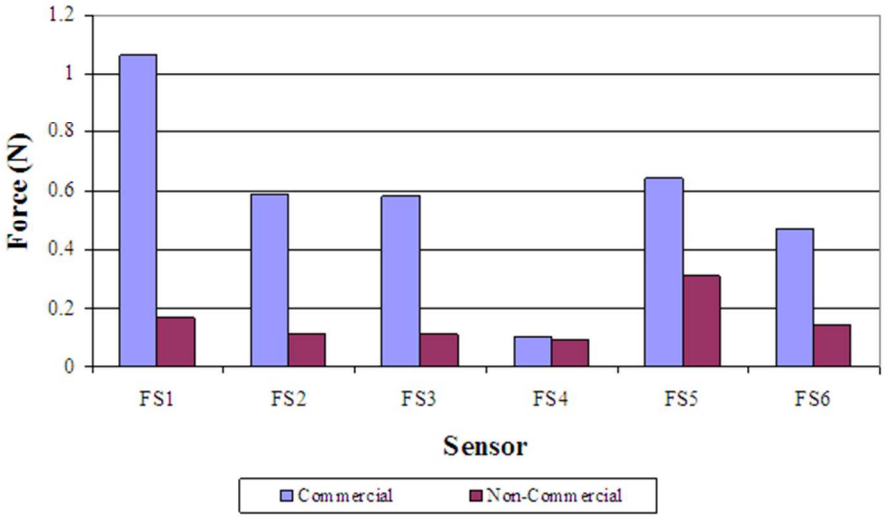

179x141mm (96 x 96 DPI)

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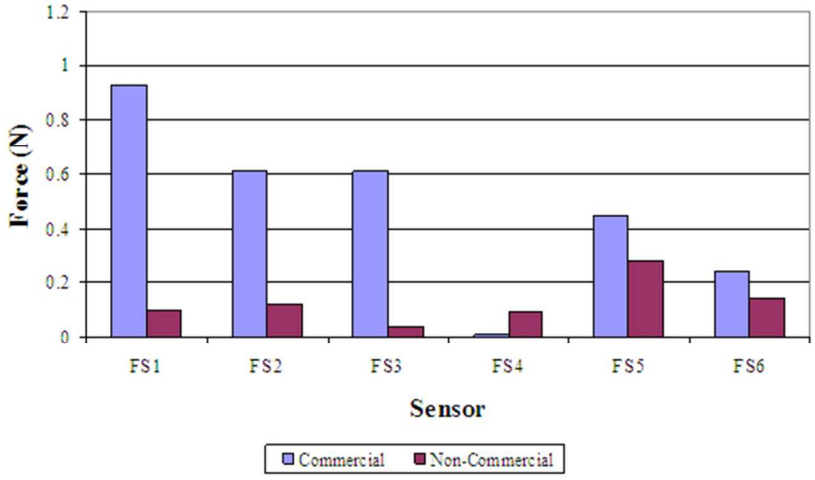

179x141mm (96 x 96 DPI)