

# Comparison of Techniques for Securing the Endotracheal Tube while Wearing Chemical, Biological, Radiological, or Nuclear Protection: A Manikin Study

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## Abbreviations:

CBRN-PPE = chemical, biological, radiological, nuclear personal protective equipment

ETT = endotracheal tube

LMA = laryngeal mask airway

NHS = National Health Service

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## Abstract

**Objective:** The objective of this study was to assess the impact of chemical, biological, radiological, nuclear personal protective equipment (CBRN-PPE) on the ability to secure an endotracheal tube (ETT) with either the Thomas Tube Holder™ or cotton tape tied in a knot.

**Methods:** Seventy-five clinicians secured an ETT in a previously intubated manikin with the Thomas Tube Holder™ and cotton tape. A mixed quantitative and qualitative research design was used to gauge actual performance times and perceptions of difficulties. Following completion of the study, 25 clinicians were interviewed to gauge their experiences of securing the ETT with both devices while wearing CBRN-PPE.

**Results:** The mean time to apply the Thomas Tube Holder was 29.02 seconds, compared with tape which took a mean of 58 seconds ( $p = 0.001$ ). Clinicians rated the Thomas Tube Holder as easier to use than tape (Mann-Whitney  $z = 9.934$ ;  $p < 0.001$ ), which was confirmed during interviews. Of the clinicians interviewed, 92% perceived that the Thomas Tube Holder provided the better method for securing an ETT, none of the clinicians identified the tape as the best method for securing the endotracheal tube while wearing CBRN-PPE. Clinicians identified that the design of the Thomas Tube Holder facilitated the gross motor movement required for application.

**Conclusions:** The Thomas Tube Holder is easier and faster to apply when wearing CBRN-PPE when compared with cotton, and the Thomas Tube Holder is perceived by the participants as being more effective at preventing accidental extubation

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## Introduction

Many lessons were learned following the responses to the sarin gas attack on the Tokyo underground in 1995. The importance of early advanced life support (ALS) interventions, including endotracheal intubation, was demonstrated in the high rate of successful resuscitation of those who presented to the emergency department in cardiorespiratory or respiratory arrest.<sup>1</sup> This also has been reported in other situations.<sup>2,3</sup> Endotracheal intubation or placement of a laryngeal mask (LMA) placement facilitates optimal oxygenation and ventilation,<sup>4</sup> but it may be required at an early stage during patient management, even before extrication and external decontamination.<sup>5,6</sup>

It also was apparent that there was a substantial risk for secondary contamination of healthcare staff<sup>7</sup> which, again, has been confirmed in other reports.<sup>3,8,9</sup> The use of appropriate chemical, biological, radiological, nuclear-personal protective equipment (CBRN-PPE) reduces the risk of secondary contamination, but also hampers the ability to perform fine manual tasks.<sup>10–13</sup>

Once the airway is secured with either an endotracheal tube (ETT) or Laryngeal Mask Airway (LMA), it must be “tied in” to prevent accidental extubation. Currently, a number of techniques exist to secure an ETT and/or

Background	Total in Study	Total Interviewed	%
Anesthetic Consultants	5	4	80
Anesthetic Trainee	10	5	50
Emergency Physician Consultant	8	4	50
Emergency Physician Trainee	17	5	23
Prehospital Care Doctor	4	2	50
Paramedic	17	3	17.5
Resuscitation Officer	6	2	33

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**Table 1**—Background of interviewees  
Total interviewed = 25 from a population of 75

LMA, but there are limited data as to the ideal technique to be used while wearing CBRN-PPE.<sup>4</sup> A number of studies previously have highlighted difficulties in securing the ETT in place while wearing CBRN-PPE.<sup>10–13</sup> Hender *et al* noted that experienced anesthetic teams reported that securing the ETT following successful intubation was the single most difficult aspect of airway management and concluded that more research was required.<sup>10</sup> To date, no such research has been published in peer-reviewed journals.

### Methods

A mixed quantitative and qualitative research design was used to gauge actual performance times and perceptions of difficulties utilizing a five-point Likert scale questionnaire. Following completion of the study, 25 clinicians (Table 1) were interviewed to ascertain their experiences of attempting to secure the ETT with both the Thomas Tube Holder™ and the cotton tape tie.

### Power Calculation

Data from studies by Flaishon *et al*<sup>12</sup> and Suyama *et al*<sup>14</sup> provided estimates of means and standard deviations for various skill completion times while wearing CBRN-PPE. Flaishon *et al*<sup>12</sup> and Suyama *et al*<sup>14</sup> demonstrated that standard deviations were observed to be approximately proportional to mean completion times, at a ratio of between one-quarter to one-half of the mean. Using supplementary data from Garner *et al*,<sup>11</sup> who reported a mean (41 seconds) and 95% confidence interval (24 seconds, 58 seconds) for “tying off” an ETT, it was determined that, using a ratio of standard deviation to mean of 0.5, 64 clinicians would enable the estimation the mean “securing” time, with 95% confidence, to within plus or minus 5% of the true mean time. No “non-suited” controls were used, as the intension was to compare the impact of CBRN-PPE on skill performance.

### Selection of Participants

Entry criterion was based on those clinicians who normally would secure an ETT/LMA in-place following the successful intubation of an apnoeic patient within the institution or within the wider UK health system.

Data were collected during CBRN-PPE familiarization training, which 75 eligible clinicians attended. Participants were informed at enrollment that they would be approached for interview to gauge their experiences of performing the skills while wearing CBRN-PPE, with the exception of the prehospital doctors all interviewees responded to internal posters. Prehospital doctors were recruited following a single e-mail. No minimum or maximum number was set with regard to the number of interviews to be completed. Recruitment was set to be ceased once representations from all sub-specialities of clinicians enrolled in the study were interviewed (Table 1) and no new information was obtained during interviews, thereby achieving theoretical “saturation”. Thirty-six clinicians had previously worn National Health Service CBRN-PPE. This study was subjected to institutional ethical review and all participants provided written informed consent.

### Selection of Techniques

The choice of comparing tying the ETT with cotton tape (Spentex™ 0.5 cm wide and pre-cut to 50 cm) against the Thomas Tube Holder (Laerdal Medical, Figure 1) represented current practice within the institution’s emergency department (tape or Thomas Tube Holder) and anesthetic department (solely tape). All participants had previous experience of using either technique while wearing normal clothing; no participant previously had attempted to “tie in an ETT/LMA” while wearing CBRN-PPE. Carlson *et al* recently evaluated the Thomas Tube Holder and demonstrated its clinical effectiveness.<sup>15</sup> No specified technique for tying the tape was prescribed during this study, as there is no “institutional standard”, and clinicians currently develop a personal preference. The most commonly adopted technique utilized a single clove hitch around the ETT and a single knot tied against the patients face/cheek (Figure 2).

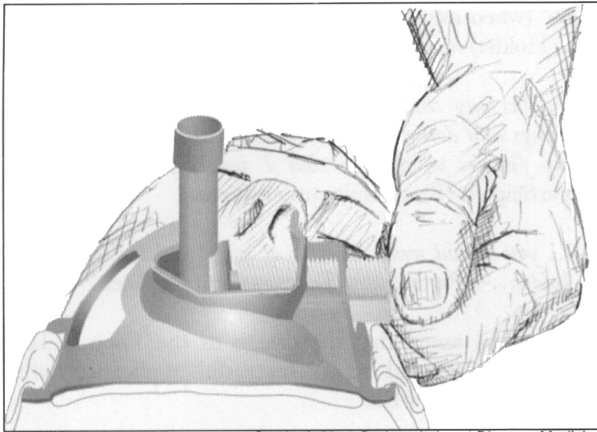
### CBRN-PPE

The NHS level-C CBRN-PPE that previously has been issued to all emergency departments and ambulance services in the UK was utilized for this study.<sup>16</sup> The NHS level-C suit incorporates a fully encapsulated suit, a panoramic visor, and provides filtered air. The NHS CBRN-PPE’s panoramic visor provides maximum vision,<sup>16</sup> but the NHS suits retain butyl gloves (Figure 2) that are known to adversely affect fine motor skill performance.<sup>17–18</sup>

Clinicians were asked to secure a previously intubated (size 7 mm ETT) Laerdal manikin while wearing NHS CBRN-PPE, using both tape (tied as they normally would an ETT) and the Thomas Tube Holder.

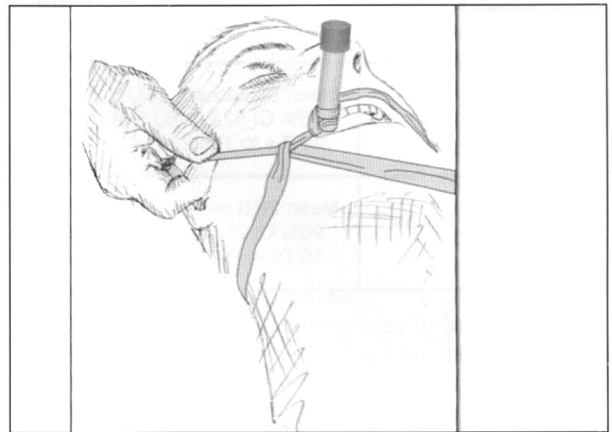
Each clinician was timed from when they picked up either a pre-cut piece of tape or the Thomas Tube Holder with the clock stopping when the clinician successfully completed the skill. The clinicians were asked to pull on the ETT to assess the degree of security, and state which device they perceived to be most secure. The clinicians assessed the degree of difficulty with regards to the use of each method using a 5-point Likert scale (1 = easy, 5 = difficult).

Subsequently, 25 clinicians (Table 1) were interviewed to gauge their opinions as to why one technique was either more difficult or easier to use than was the other.



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Figure 1—Thomas Tube Holder



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Figure 2—Cotton tie trachy tape

Question	Answers
<p>1. What did the suit feel like?</p>	<ul style="list-style-type: none"> <li>- Clumsy</li> <li>- Warm...a little bit claustrophobic</li> <li>- Challenging</li> <li>- Detached</li> <li>- Cumbersome</li> <li>- You loose your peripheral vision</li> <li>- Big gloves</li> <li>- Your tactile dexterity goes out the window</li> <li>- Dexterity, although difficult... wasn't impossible</li> <li>- It's almost like having to relearn how to clumsily do something</li> <li>- (forward) Vision was ok</li> <li>- No finesse in the suit...it's all big movements</li> <li>- Moving around was restrictive</li> <li>- As expected co-ordination and hand movements were difficult</li> <li>- I'm glad I worn the suit...I now know what to expect</li> <li>- More difficult than expected</li> <li>- Certainly more difficult than without the suit</li> </ul>
<p>2. How did you find securing the ETT with trachy tape?</p>	<ul style="list-style-type: none"> <li>- Impossible</li> <li>- Tying knots was absolutely impossible</li> <li>- You can't feel the tie you're trying to manipulate</li> <li>- Getting the tie under the neck was difficult</li> <li>- You lose fine motor skill with the butyl gloves</li> <li>- I couldn't feel my fingers or the tie I was holding</li> <li>- Things got easier the 2nd time...but not tying it was consistently difficult</li> <li>- The tie sometimes slides between the (my) fingers</li> </ul>
<p>3. How did you find securing the ETT with the Thomas Tube Holder™?</p>	<ul style="list-style-type: none"> <li>- It was much easier</li> <li>- It was easier to secure around the back of the neck</li> <li>- Much easier to control</li> <li>- On the whole I found the mechanical device very easy</li> </ul>

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Table 3—Experience of wearing chemical, biological, radiological, nuclear personal protective equipment (CBRN-PPE) and attempting to secure the endotracheal tube (ETT)

*Quantitative Analysis*

A multiple, linear regression model (taking account of the non-independence of observations within clinicians) was fitted to the 150 completion times. Completion times had a skewed distribution and variances that differed by method. Therefore, a bootstrap method, free from parametric assumptions, was used to derive estimates of error variance for the tests of statistical significance, using 10,000 bootstrap samples. Independent effects of method, famil-

ilarity with CBRN-PPE, professional group and clinician “order” (i.e., the order that clinicians “came through the door”) were tested.

Clinicians’ ratings of degree of difficulty of each method and their perceptions of which device was most secure were summarized descriptively. Analysis was undertaken using STATA (V9.2, StataCorp 2005, TX), and an alpha of 5% was used to detect type-1 error.

Device	Results
Cotton Tape n = 75	Mean 58 seconds (SD = 26.3 s; 95% CI 52.0 s–63.9 s) range 19.7 s to 148.2 s
Thomas Tube Holder™ n = 75	Mean 29.0 seconds (SD = 6.5 s; 95% CI 27.6 s–30.5 s) range 16.7s to 48.9s.

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**Table 3**—Speed of application of Thomas Tube Holder™ versus Trachy Tape

### Qualitative Analysis

All interviews were recorded and then transcribed. Each response was coded, and themes were identified. The interviews were semi-structured, using open questions (Table 2) targeted to identify participant's opinions as to ease of use with each technique. Participants were anonymous.

### Results

#### Quantitative

The mean of the times required to apply the Thomas Tube Holder was 29.0 seconds compared with tape, which took a mean of 58 seconds ( $p = 0.001$ ; Table 3). The participating clinicians rated the Thomas Tube Holder as easier to use than tape (Mann-Whitney  $z = 9.934$ ;  $p < 0.001$ ), with the median rating for the Thomas Tube Holder equalling 2, compared to 4 for the tape. This finding was confirmed by the difference in the upper range of skill completion (Table 2), in which the slowest application of the Thomas Tube Holder was three times faster than the slowest application of tape. Of the clinicians, 92% (69/75) perceived that the Thomas Tube Holder™ provided the most effective method of securing an ETT, with the other six stating that both methods were equally effective. No clinician identified the tape as the best method for securing the endotracheal tube.

Mean securing times (Table 2) differed significantly by method ( $p < 0.001$ ), with, on average, the Thomas Tube-holder taking 29 seconds less to secure than tape (95% CI = 23.2 seconds–34.7 seconds). Previous familiarity with CBRN-PPE did not improve performance ( $p = 0.916$ ), nor were there any differences by professional group ( $p = 0.445$ ), or clinician "order" ( $p = 0.765$ ) (Table 4).

#### Qualitative

Of the interviewees, 24 out of the 25 expressed difficulty with regards securing the ETT with tape with 24 interviewees stating a preference for the Thomas Tube Holder. One interviewee (Participant K, Consultant Emergency Physician) stated that both techniques were difficult to use and secured the ETT to the same degree. This reflects findings from the questionnaire.

Interviewee's experiences of wearing the CBRN-PPE and attempting to secure the ETT are in Table 3. The principal reason given by all 25 interviewees for difficulty with regards securing the ETT was the loss of manual dexterity due to the CBRN-PPE gloves. In addition, a number of interviewees stated the absence of "weight" and/or "lose of

touch" (when using the tape as compared with the Thomas Tube Holder) made handling the tape more difficult (Table 3).

*...The only thing I really struggled with was tying things and doing very fine motor skills...I couldn't feel my fingers or the tie that I was trying to tie.—Participant (S), consultant anesthetist*

*... you should scrap the idea of tying and use the tube holder...—Participant (J), resuscitation officer*

Interviewees noted that the design of the Thomas Tube Holder was integral to its successful application while wearing CBRN-PPE.

*...Tying the tube was difficult because you can't feel the cloth, So you're going purely on sight...on the whole I found the Mechanical (tube holder) device very easy.—Participant (D), anesthetic trainee*

*...The tie sometimes slides between the (my) fingers.—Participant (Y), anesthetic trainee*

Some of the clinicians thought the cotton tape was ineffective.

*...That's the best I can do [when applying trachy tape]... but I wouldn't accept it in my Resuscitation room—Participant (S), emergency physician*

### Discussion

Respiratory failure may result from exposure to toxic chemicals<sup>5,19</sup> with associated reduced levels of consciousness leading to reduced respiratory drive and loss of airway reflexes. In addition, associated increases in airway secretions, mucosal edema, bronchospasm, and laryngospasm all reduce oxygen delivery.<sup>19</sup> Prompt airway management is instrumental in patient survival following a chemical incident.<sup>1,5,6</sup> Hendler *et al* noted that experienced two-person anesthetic teams wearing CBRN-PPE reported that tying in a successfully placed ETT was the most difficult aspect of airway management, increasing the time to complete the skill successfully by upwards of 73%. As in the current study, Hendler *et al* did not prescribe a set "technique" for tying in the ETT, but allowed the clinician to utilize their standard technique.<sup>10</sup> These difficulties were confirmed by Garner *et al*,<sup>11</sup> and subsequent studies have avoided evaluating securing the ETT.<sup>12,13,20</sup>

When clinicians were observed trying to tie the ETT with tape during this study, the chemical resistant gloves prevented the maintenance of traction on the knot (confirmed during interviews (Participant Y)). This resulted in the knot "slipping" and becoming very loose, and it is arguable that this situation would be worsened in the presence of increased salivation or vomit. This loss of traction resulted in clinicians perceiving cotton tape to be ineffective.

This degradation of ETT tying capability is mainly due to the CBRN-PPE "rubber gloves" that reduce two-handed fine motor skill (integral to knot tying) by 55%.<sup>21</sup> The subsequently poorly tied ETT increases the risk of accidental extubation, especially during patient movement or while

Factor	Co-Efficient (seconds)	Bootstrapped Standard Error	95% Confidence Interval	Overall <i>p</i> -value
Thomas Tube Holder™	-28.9	2.9	(-34.7, -23.2)	<0.001
Previous familiarity with CBRN	0.34	3.3	(-6.0, 6.7)	0.918
Professional group (compared to paramedics/resuscitation officers/prehospital doctors)				
Anesthetists	2.7	4.2	(-5.5, 10.9)	0.445
Emergency Medical Physicians	4.8	3.9	(-2.9, 12.5)	
Clinician "order"	-0.02	0.1	(-0.17, 0.13)	0.769
Constant	55.9	4.9	(46.4, 65.5)	

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**Table 4**—Details of results from multiple regression of method completion times while suited in chemical, biological, radiological, or nuclear personal protective equipment (CBRN-PPE)

undertaking procedures such as log-rolling for decontamination, as well as during transfer to the hospital.<sup>22</sup>

Key to the successful application of the Thomas Tube Holder is its design. The combination of a ratchet screw (Figure 2), for tightening the grip on the ETT, and the Velcro incorporated into the plastic strap for passing under the patients head are primarily gross motor skills, a skill set that is retained while wearing CBRN-PPE.<sup>23</sup>

Although no "non-suited" controls were used during this study, the times to secure the ETT with the Thomas Tube Holder while wearing CBRN-PPE are not dissimilar to the times reported by Owen *et al* (mean = 28.1 ±8.2, range 18.1–54.9 seconds) but demonstrate a significant impact when using the same make of cotton tape (mean = 33.1 ±8.6, range 22.3–60.3 seconds).<sup>24</sup>

Adhesive tape, which is used in pediatric airway management, was not evaluated, since its use is not common practice within the organization. Garner *et al*<sup>11</sup> questioned the effectiveness of "sticky tape" as not being able to secure the ETT in the presence of increased salivation although zinc oxide tapes, which is effective at securing the ETT,<sup>15,24</sup> may overcome the issue with regards increased salivation. However, the loss of fine motor skills is likely to adversely affect the time required to prepare adhesive tape while wearing CBRN-PPE, and the highly adhesive zinc oxide tape is likely to stick to the CBRN-PPE gloves (highlighted during interviews—Participant B).

Familiarity with equipment to be used during an emergency remains an important consideration. All participants in this study previously had used the Thomas Tube Holder (either clinically or in training) although all participants

were more familiar with using a cotton tie to secure an ETT/LMA that reflected the hospitals "in theatre practise". Training and practice with emergency airway equipment (to include securing devices/techniques) will remain an important aspect of CBRN response capabilities. However, this study suggests that the design of the Thomas Tube Holder makes it easier to use than the more traditional cotton tie.

*Limitations*

Due to the number of participants required and ethical issues, a manikin was used in this study. Due to the number of participants and ethical issues, this study was restricted to humans. In addition, it was not possible to recreate increased upper airway salivation that is likely to be encountered following a CBRN incident.

**Conclusions**

The cumbersome nature of CBRN-PPE, particularly the protective gloves, greatly affects the use of fine motor skills. This adversely affected the ability to secure the ETT with cotton tape, but not with the Thomas Tube Holder. The design of the Thomas Tube Holder, which incorporates a ratchet screw for tightening the holder against the ETT and plastic applicator for securing the velcro together, retains gross motor skills. Therefore, this study would suggest that following a CBRN incident, should a patient's airway need protecting with an ETT or LMA prior to decontamination, the Thomas Tube Holder offers an effective and speedy option for minimizing unintentional extubation and should replace the use of tape.

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