Original contribution

Proper insertion depth of endotracheal tubes in adults by topographic landmarks measurements

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**Abstract**

**Study Objective:** To evaluate a new method of endotracheal tube (ETT) positioning relative to carina, based on external topographic landmarks.

**Design:** Prospective, randomized, crossover study.

**Setting:** Operating room, university hospital.

**Patients:** 200 American Society of Anesthesiologists (ASA) physical status I-II patients (100 women and 100 men) scheduled for elective surgery with general anesthesia.

**Interventions:** ETT insertion depth was topographically determined by adding the distance measured (in cm) from the right mouth corner to right mandibular angle to the distance measured from the right mandibular angle to a point situated on the center of a line running transversally through the middle of the sternal manubrium. This method was compared to the 21/23 cm insertion depth method.

**Measurements:** ETT position was assessed fiberoptically. The main end point was considered the percentage of ETT tips situated more than 25% higher or lower than a predetermined “best” tip position (4 cm above the carina).

**Main Results:** There were 58.5% ETT tips positioned too closely (<3 cm above the carina) to the carina with the control method and 24% with the study method ($P = 0.0001$). No ETT tip was too high (>5 cm above the carina). The tip-carina distance was shorter in women (2.7 ± 2.5 vs 3.6 ± 2.2 cm in men $P = 0.0001$) and in those aged more than 65 years (2.8 ± 2.4 vs 3.4 ± 2.4 cm with age less than 65 years; $P = 0.012$) only with the 21/23 cm method.

**Conclusions:** With our new ETT positioning method, there were fewer ETTs positioned outside the desired range of distance to carina. Our method may be especially valuable in women and in patients older than 65 years.

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1. Introduction

The incidence of bronchial intubation has not been clearly defined. According to the ASA Closed Claims Project, bronchial intubation accounts for 2% of the adverse respiratory events in adults and 4% in pediatric patients [1,2]. Schwartz et al [3] found an incidence as high as 15.5% of inappropriately placed endotracheal tubes (ETTs) as verified by radiography, with a higher frequency in women. A commonly used method of positioning the orally inserted ETTs is securing them at the upper incisors (or gums) or at the lips level at 23 cm ETT marking in men and 21 cm marking in women [4,5].

Even with the 21/23 cm approach, accidental bronchial intubations still occur because this method does not take into consideration interindividual variability in head and neck anatomical proportions. We hypothesized that our method of estimation of ETT insertion depth by external topographic measurements is associated with fewer inappropriate ETT tip positioning as compared with the 21/23 cm method.

2. Materials and methods

The Wolfson Medical Center’s Institutional Review Board approved the study protocol, and written, informed consent was obtained from each patient. Two hundred ASA physical status I-II patients (100 women and 100 men) scheduled for elective surgery with general anesthesia, were enrolled in the study. Patients with upper airway or pulmonary problems, neck and/or chest distortion, previous difficult intubation, or patients at risk for pulmonary aspiration of gastric content were excluded from the study.

The desired distance from the ETT’s tip to carina measured fiberoptically is 2.5 to 4 cm [6]. For safety purposes [7], we used the upper limit of this distance (ie, 4 cm) as our “best” ETT tip-carina distance.

A more than 25% upward or downward deviation from the 4 cm best ETT tip-carina distance (ie, <3 or >5 cm) was considered statistically significant.

In this prospective, double-blind, crossover study, each patient underwent two intubation procedures: as a control, the ETT was positioned and secured with the 21 cm marking for women and the marking 23 cm for men at the right mouth corner. With the topographic (study) method, the ETT insertion depth (in cm) was determined by adding the distance measured from the right mouth corner to right mandibular angle to the distance measured from the right mandibular angle to the center of a line drawn transversally through the middle of the sternal manubrium (Fig. 1). Our intubation method was based on the topographic correlation between the carina and the manubriosternal junction (angle of Louis) [8] (Fig. 2). We determined that the external topographic position of the ETT’s tip should be at the junction between the superior and inferior half of the sternal manubrium (above the angle of Louis, ie, above the carina). The tip-carina distance was assessed fiberoptically and was measured on a printed scale in millimeters attached to the fiberscope (Olympus LF-GP, 4.1 mm ED, Olympus Medical Systems Corp 2951,Tokyo, Japan) (Fig. 3). The best position was an ETT tip situated 3 to 5 cm above the carina. Fiberoptic examination from above was also

Fig. 1 The topographic intubation method. The distance from the right corner of the mouth to right mandibular angle is added to the distance measured from the right mandibular angle to a line running transversally through the middle of the sternal manubrium. The sum of these two distances determines the final endotracheal tube insertion depth in centimeters.

Fig. 2 Topographic position of the carina relative to the angle of Louis. The external topographic imaginary level of carina corresponds to the intersection between the manubrium and sternal body (angle of Louis).

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performed to detect whether the ETT cuff was positioned above the vocal cords.

Induction and maintenance of anesthesia were standardized. Intubation was performed with the head and neck in neutral position. Tubes (Portex, SIMS Portex Ltd, Hythe, Kent, UK) were uncut and were of internal diameter (ID) 8 mm for men and 7.5 mm for women.

Randomization for the order in which each ETT positioning method was tested was performed with the sealed, opaque envelope technique.

After the first intubation (with either method), the ETT was removed and reinserted with the second intubation method. After each insertion, ETT tip-carina fiberoptic measurements were performed by a second, “blinded” anesthesiologist. After the second set of measurements, the tip of the ETT was positioned to 4 cm above the carina until the end of surgery.

The entire measuring process takes up to 30 seconds.

2.1. Data analysis

In a pilot study of 50 patients, we found a 20% difference in the percentage of ETT tips outside the previously mentioned desired tip-carina distance range, between the two intubation methods (40% with the 21/23 cm method vs 20% patients with our topographic method).

With a sample size of 200 subjects, the present study was designed to have 90% power to detect a true ≥20% by-method difference in frequency of tube misplacement using t test for paired samples, assuming a two-sided α of 0.05. Logistic regression analysis was performed to determine factors associated with malpositioning (need for repositioning) using each of the methods. In each of the determinants, gender, age, height, and weight were included as covariates.

For continuous variables, descriptive statistics were calculated and reported as means ± standard deviation. Normalcy of distribution of continuous variables was assessed using the Kolmogorov-Smirnov test (cutoff at P = 0.01). Categorical variables were described using frequency distributions and are presented as absolute numbers and frequency (%). The McNemar test was used to detect differences in categorical variables between each of the tube insertion methods. The χ² test was used to compare categorical variables by gender and age. The t test for paired samples was used to compare continuous variables measured during each of the tube insertion methods. All tests were two-sided and considered significant at P < 0.05.

3. Results

All patients (100 men and 100 women) completed the study. There were 5 (2.5%) bronchial (right) intubations with the 21/23 cm method and none with the topographic method (Table 1). With both techniques, no ETT tip was positioned at a distance more than 5 cm above the carina. There were more (P = 0.0001) ETTs positioned too closely to the carina (ie, <3 cm) with the control method (Table 1).

Continuous variables were compared by gender and age (Table 2). Age was lower (P = 0.004), whereas weight and height were higher in men (P = 0.0001 and 0.0001, respectively). Weight was higher in patients older than 65 years, whereas height was higher in the patients younger than 65 years (P = 0.0001, P = 0.06, and P = 0.0001, respectively). Table 2 also shows that the tip-carina distance was significantly shorter in women and with those with age more than 65 years, only for the 21/23 cm intubation method (P = 0.0001 and P = 0.012, respectively). Gender and age did not affect the tip-carina distance with the topographic method. Categorical variables by gender and age are presented in Table 3. Mallampati class was higher in men (P = 0.03). Although all (n = 5) inadvertent bronchial intubations occurred in women, the significance of difference compared with men was marginal (P = 0.06). A thyromental distance less than 6 cm was not associated with more bronchial intubations or shorter tip-carina distances.

![Fig. 3 Fiberoptic measurement of the endotracheal tube (ETT) tip position relative to the carina. First, the fiberoptic bronchoscope (FOB) is advanced to the depth of the carina. This position is marked by tape attached to the FOB. Then the tip of the FOB is withdrawn until the line of the ETT is first visualized. This position is also marked by tape (in the picture, closer to the ETT connector) on the FOB. The measurement is performed with a scale in millimeters attached to the FOB.](image)
The model of need for repositioning using the 21/23 cm method indicates that gender was significantly associated with repositioning, such that women experienced a relative increase of 65.5% needing tube repositioning (odds ratio, 0.34; 95% confidence interval, 0.12-0.92; \( P = 0.03 \)). Age was associated with increased risk of repositioning, such that each one year increase in age conferred a 2.5% increase in risk for repositioning (odds ratio, 1.025; 95% confidence interval, 1.007-1.044; \( P = 0.007 \)). Height and weight were not associated with repositioning risk.

4. Discussion

Proper positioning of the ETT tip relative to the carina after endotracheal intubation remains a concern. Auscultation of breath sounds for detection of bronchial intubation is not fail-safe [9]. In patients with cardiac arrest intubated by advanced cardiac life support (ACLS) course-certified physicians, the incidence of bronchial intubation was 28% [10]. In addition, properly positioned ETTs might move later into one of the bronchi with a change of the patient’s position [11], flexion or extension of the head [12], or peritoneal insufflation [11,13].

Proper ETT positioning is especially critical in pediatric anesthesia patients [14] and in children undergoing medical transport [15]. Further study should be undertaken to assess our intubating method in pediatric population.

The present study confirms the applicability and reliability of our intubation method based on external topographic landmark measurements.

The practitioner can easily memorize this method that unifies 2 measurement lines drawn from the mouth angle to jaw angle and from there to the midline of the sternal manubrium.

No bronchial intubation occurred with this method, and the ETT tip-carina distance was more frequently placed in a proper position compared with the 21/23 cm method.

Our method may be especially useful in women and elderly patients who have shorter tip to carina distances, although measured with the 21 cm/23 cm but not with the topographic method.

We are aware that the 21/23 cm method is a positioning method commonly taught to inexperienced personnel, such as accident and emergency trainees. In clinical practice, many experienced users of ETTs position the ETT cuff just below the vocal cords to minimize bronchial intubation. However, individual anatomical characteristics of the airway are not considered by many other intubation techniques such as inserting the proximal end of the cuff one cm below the vocal cords [16] or calculation of intubation depth according to patient’s height [17].

Owen and Cheney [4] claim that the vocal cords–carina distance ranges between 10 and 15 cm and varies with patient height. This observation was not confirmed by our study, where patient height did not correlate with ETT tip to carina distance. In a computed tomography study of the neck, Eagle [17] failed to find a correlation between patient height, length of trachea, and appropriate ETT length. In addition, routine airway assessment often reveals that some tall patients have short necks.

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women (n = 100)</th>
<th>Men (n = 100)</th>
<th>( P )</th>
<th>Age &lt;65 y (n = 102)</th>
<th>Age &gt;65 y (n = 98)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>63 ± 18</td>
<td>56 ± 17</td>
<td>0.004</td>
<td>45 ± 13</td>
<td>74 ± 7</td>
<td>0.0001</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.5 ± 5.8</td>
<td>177.2 ± 5.5</td>
<td>0.0001</td>
<td>172.3 ± 8.8</td>
<td>167.3 ± 9</td>
<td>0.0001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.2 ± 10</td>
<td>79 ± 9</td>
<td>0.0001</td>
<td>75.3 ± 11</td>
<td>71 ± 11</td>
<td>0.006</td>
</tr>
<tr>
<td>ETT tip, carina distance with the control method (cm)</td>
<td>2.7 ± 2.5</td>
<td>3.6 ± 2.2</td>
<td>0.0001</td>
<td>3.4 ± 2.4</td>
<td>2.8 ± 2.4</td>
<td>0.012</td>
</tr>
<tr>
<td>ETT tip, carina distance with the topographic method (cm)</td>
<td>3.4 ± 1.3</td>
<td>3.4 ± 1.2</td>
<td>0.89</td>
<td>3.4 ± 1.2</td>
<td>3.5 ± 1.3</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Results are expressed as means ± SD or medians (ranges).

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women (n = 100)</th>
<th>Men (n = 100)</th>
<th>( P )</th>
<th>Age &lt;65 y (n = 102)</th>
<th>Age &gt;65 y (n = 98)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyromental distance &lt;6 cm %</td>
<td>25</td>
<td>21</td>
<td>0.50</td>
<td>24</td>
<td>22</td>
<td>0.86</td>
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<tr>
<td>Mallampati, %</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Thyromental distance &lt;6 cm %</td>
<td>70</td>
<td>54</td>
<td></td>
<td>62</td>
<td>62</td>
<td>0.23</td>
</tr>
<tr>
<td>Mallampati, %</td>
<td>30</td>
<td>43</td>
<td></td>
<td>35</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Laryngoscopy grade, %</td>
<td>0</td>
<td>3</td>
<td></td>
<td>3</td>
<td>0</td>
<td>0.07</td>
</tr>
<tr>
<td>Bronchial intubation, n (%)</td>
<td>5 (5)</td>
<td>0</td>
<td>0.06</td>
<td>3 (2.9)</td>
<td>2 (2)</td>
<td>0.68</td>
</tr>
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</table>
In conclusion, with our simple intubation method based on external topographic measurements, the ETT tip is placed at a safe distance above the carina, thus precluding the occurrence of accidental bronchial intubation or extubation. This technique may be particularly useful for intubation in women and in elderly patients.

References