Accuracy of a New Body Length-based Formula for Predicting Tracheal Tube Size in Chinese Children

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Background: Variations in body weight and length (height) in children in the same age group have increased. Traditional age-based formulas often fail to predict the correct endotracheal tube (ETT) size. In our previous study, we devised a new length-based formula as follows: ETT internal diameter (ID) (mm) = 2 + (body length in cm/30). The current study was undertaken to assess the accuracy of this formula in Chinese children.

Methods: The ETT size was selected according to this length-based formula for 336 children who required tracheal intubation during general anesthesia. Incidences of tube change were recorded. Statistical analysis was performed using the chi-square test for differences in accuracy between age groups and body length groups.

Results: The length-based formula predicted a suitable ETT size in 277 (82.4%) of 336 subjects. There were 59 (17.6%) reintubations. Only 5 (1.49%) patients needed two tube changes when the correct ETT size was 1 mm larger or smaller than predicted. There were no statistically significant differences between age groups or length groups.

Conclusions: The length-based formula ID (mm) = 2 + body length in cm/30 has high accuracy in predicting the appropriate ETT size in Chinese children. (Chang Gung Med J 2008;31:276-80)

Key words: endotracheal tube size, children, age, body length, height
length had the best correlation with the size of an uncuffed oral ETT. We obtained the following formula: internal diameter (ID) (mm) = 2+ length (cm)/30.(13)

Variations in body weight and length (height) in children in the same age group have increased. Traditional age-based formulas frequently fail to predict the correct ETT size. In addition, body length is the easiest parameter to obtain under emergency conditions. This new length-based formula has been used clinically in our daily practice in general anesthesia for children. The current study was undertaken to assess the accuracy of this length-based formula.

**METHODS**

From August 2003 to February 2004, 336 physical status I or II (American Society of Anesthesiologists) children, aged 1.5 months to 6 years, who were undergoing general anesthesia with oral endotracheal intubation for minor pediatric surgery were enrolled in the study. The study protocol was approved by our Ethics Committee and informed consent was signed by parents or guardians. Premature children and those with abnormal airways, abnormal growth, and upper respiratory tract disease were excluded.

All children were fasting and had no premedication. Anesthesia was induced by mask ventilation with oxygen, nitrous oxide and sevoflurane. Intubation of the trachea was facilitated with intravenous rocuronium bromide 0.6 mg/kg. Polyvinyl chloride ETTs (Mallinckrodt Laboratories, Athlone, Ireland), ranging in size from ID 4 to 6.5 mm were used. The ETT size was selected with a reference chart (Table 1) based on the following formula: ID (mm) = 2+ length (cm)/30.

Immediately following confirmation of tracheal placement of the tube, an anesthesiologist was assigned to monitor air leakage by auscultation on the skin over the larynx with a stethoscope using the method described by Finole et al.(14) The ETT size was regarded as suitable when it smoothly passed though the glottis and provided minimal air leakage as the ventilation circuit was subjected to 20-25 cmH2O. An ETT one half-size larger was used to replace the first ETT if there was air leakage at 10 cmH2O. A one half-size smaller tube was used if the former could not pass easily though the cricoid cartilage of the trachea. Incidences of reintubation because of incorrect ETT size were recorded.

Statistical analysis was done using the chi-square to test for differences in accuracy of the length-based formula between age groups and length groups. A $p$ value of < 0.05 was considered significant.

**RESULTS**

The study included 336 patients ranging in age from 1.5 months to 6 years, with a body length from 53 cm to 124 cm. There were 269 boys and 67 girls. The age and gender distribution of the patients are shown in Table 2.

The length-based formula predicted the appropriate ETT size in 277 (82.4%) of 336 patients. There were 59 (17.6%) reintubations. Of these, 10 (16.9%) subjects were reintubated using a smaller ETT size and 49 (83.1%) subjects using a larger ETT size than predicted. Only 5 (1.49%) of the 336 subjects needed to be reintubated twice because the best-fit ETT size was 1 mm larger or smaller than predict-
ed by the length-based formula. No patients were taller than 127.5 cm so the ETT size ID = 6.5 mm was not used.

To evaluate age factors in tube size selection, study candidates were allocated into 6 age groups. (Table 3) The accuracies between age groups were compared using chi-square statistical analysis. The difference was not statistically significant (p = 0.94).

According to the reference chart for ETT size, the subjects were divided into 5 different body length groups (Table 4). The case numbers in two groups, > 52.5-67.5 cm and > 112.5-127.5 cm, were much smaller than in the other groups. In the > 52.5-67.5 cm group, the formula predicted the correct ETT size in 11 (73.3%) of 15 subjects. In the > 112.5-127.5 cm group, the formula predicted the appropriate ETT size in 25 (83.3%) of 30 subjects. The accuracies between body length groups were compared using chi-square statistical analysis. The difference was not statistically significant (p = 0.308).

**DISCUSSION**

Selecting an ETT with an appropriate diameter is a major task for successful tracheal intubation in pediatric patients. A proper size ETT is vital for the prevention of perioperative and postoperative complications due to the unique structure of the pediatric airway. A suitable fitting ETT helps prevent aspiration of stomach contents and provides a better system for controlled or assisted ventilation. An ETT that is too tight may induce mucosal damage, ischemic injury, and edema within the subglottic structures, and could lead to postextubation croup.(15)

In western countries, the Broselow tape is a well-known tool designed to estimate body weight and ETT size based on body length in emergency pediatric patients. The Broselow tape has been validated for selection of ETT size in pediatric patients in the U.S. and Europe.(16-18) It is recommended in Pediatric Advanced Life Support courses (PALS). The accuracy of the Broselow tape in estimating ETT size has ranged from 55% to 77%. The accuracy of our length-based formula was 82.4%. This formula predicted the appropriate ETT size within +/-0.5 mm in 331 (98.5%) candidates. A tape designed from the reference chart for ETT size selection (Table 1) could be very helpful in general anesthesia and critical care practice in Chinese children.

Although the predictability of this formula is quite satisfactory, some tube replacements are still needed. One possible alternative may be the use of cuffed endotracheal tubes instead of uncuffed tubes. The studies of Deakers et al. and Newth et al. showed no differences in the incidences of post-extubation complications between cuffed and uncuffed ETT in pediatric intensive care.(19,20) A recent report by Dullenkopf et al. proved that using an ETT with a high volume-low pressure polyurethane cuff is not associated with a higher incidence of postextubation complications.(21) The sizes of cuffed ETT still need to be carefully selected and cuff pressures must be meticulously monitored to remain at “just seal” or “minimal occlusion pressure”. However, all cuffed pediatric tubes have a smaller inner diameter, and they are more expensive. The smaller diameter can cause higher resistance to gas flow, increasing the

<table>
<thead>
<tr>
<th>Age</th>
<th>Correct tube size</th>
<th>Tube changed</th>
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<tbody>
<tr>
<td>1.5 mo-1 yr</td>
<td>84.1% (37/44)</td>
<td>15.9% (7/44)</td>
</tr>
<tr>
<td>&gt; 1 yr-2 yr</td>
<td>80.2% (73/91)</td>
<td>19.8% (18/91)</td>
</tr>
<tr>
<td>&gt; 2 yr-3 yr</td>
<td>81.7% (58/71)</td>
<td>18.3% (13/71)</td>
</tr>
<tr>
<td>&gt; 3 yr-4 yr</td>
<td>87.0% (47/54)</td>
<td>13.0% (7/54)</td>
</tr>
<tr>
<td>&gt; 4 yr-5 yr</td>
<td>81.4% (35/43)</td>
<td>18.6% (8/43)</td>
</tr>
<tr>
<td>&gt; 5 yr-6 yr</td>
<td>81.8% (27/33)</td>
<td>18.2% (6/33)</td>
</tr>
<tr>
<td>Total</td>
<td>82.4% (277/336)</td>
<td>17.6% (59/336)</td>
</tr>
</tbody>
</table>

* Data are given as percentages (number of cases/total).

<table>
<thead>
<tr>
<th>Length (cm)</th>
<th>Correct tube size</th>
<th>Tube changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.5-67.5</td>
<td>73.3% (11/15)</td>
<td>26.7% (4/15)</td>
</tr>
<tr>
<td>&gt; 67.5-82.5</td>
<td>75.9% (63/83)</td>
<td>24.1% (20/83)</td>
</tr>
<tr>
<td>&gt; 82.5-97.5</td>
<td>85.0% (102/120)</td>
<td>15.0% (18/120)</td>
</tr>
<tr>
<td>&gt; 97.5-112.5</td>
<td>86.4% (76/88)</td>
<td>13.6% (12/88)</td>
</tr>
<tr>
<td>&gt; 112.5-127.5</td>
<td>83.3% (25/30)</td>
<td>16.7% (5/30)</td>
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</tbody>
</table>

* Data are given as percentages (number of cases/total).
work of breathing and difficulty in tracheal suctioning. The use of a cuffed ETT would not eliminate the need to choose the correct size, but may reduce the number of tube exchanges.

This study showed no differences in accuracy between age groups or length groups. Children between 1.5 months and 6 years old, and between 53 cm and 124 cm tall, can benefit from this length-based formula to select a suitable ETT size. For children in emergency situations, body length/height is the most convenient and accurate measurement. This length-based formula is easy to remember and has a high accuracy for ETT size estimation in these situations.

In conclusion, the length-based formula, \( ID = 2 + \frac{\text{length (cm)}}{30} \), has a high accuracy (82.4%) in predicting the best-fit ETT size in Chinese children. The formula also has a high success rate (98.5%) in predicting the appropriate ET tube size within +/- 0.5 mm, with no differences in accuracy for children of different ages and lengths.

For a faultless tracheal intubation, we recommended that three ETT sizes be available for each intubation attempt. one which is the actual predicted size, one 0.5 mm smaller and one 0.5 mm larger.

**REFERENCES**

在華人兒童使用以身長為基準的新公式
來預測氣管內管尺寸之正確性

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背 景：近年來，相同年紀兒童的體重和身長 (身高) 常有很大的差異。使用傳統以年紀為基準的公式來估計氣管內管尺寸常會失敗。依據我們先前的研究，設計了一個以身長為基準的新公式：

$$気管內管內徑 (mm) = 2 + 身長 (cm)/30$$

本研究欲評估此新公式使用在華人兒童上之正確性。

方 法：336位在全身麻醉時需進行插管的兒童，氣管內管尺寸的選擇均依據此身長為基準的新公式計算。記錄需換不同管徑氣管內管的情況。使用卡方檢定的統計方式來分析在不同年齡族群及不同身長族群下，此新公式的正確性是否有所差異。

結 果：在336位的兒童中，此新公式正確預測出277位兒童 (82.4%) 所需使用最適合的氣管內管尺寸。另有59位 (17.6%) 需換不同管徑的氣管內管。其中只有5位 (1.49%) 因最適合的氣管內管尺寸較預測尺寸偏大或小於1 mm 而需換2支不同管徑的氣管內管。在不同年齡族群及不同身長族群下，此新公式的正確性在統計分析下並無顯著差異。

結 論：此以身長為基準的新公式：

$$気管內管內徑 (mm) = 2 + 身長 (cm)/30$$

在預測華人兒童最適合的氣管內管尺寸上有很高的正確性。

(長庚醫誌 2008;31:276-80)

關鍵詞：氣管內管尺寸，兒童，年齡，身長，身高