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

Ming-Hung Shih, MD; Chin-Yang Chung, MD; Bai-Chuan Su, MD; Chao-Tsen Hung, MD; Shu-Yam Wong, MD; Teresa Kit-Man Wong, MD

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

In general anesthesia and critical care practice for children, accuracy in selection of an endotracheal tube (ETT) size is important. Failing to predict a suitable ETT may increase the number of intubation attempts and prolong the intubation time. Multiple intubation interventions and use of an oversized ETT may induce airway trauma and increase the incidence of postoperative croup.[1,2] A prolonged intubation time may cause hypoxemia and complications.

In children, a proper size ETT allows easy ventilation, and an air leak at a pressure of 20-25 cmH_2O helps avoid airway morbidity.[1,3] Using an under-size uncuffed ETT may increase the potential for aspiration, lead to erratic delivery of the preset tidal volume during mechanical ventilation, and also increase anesthetic gas pollution in the operating room.

The size of a child's trachea,[4] age,[4-9] height,[9-11] weight, and fifth finger diameter[12] have been used clinically as prediction parameters for ETT size. In our previous study of 533 Chinese children, body

From the Department of Anesthesiology, Chang Gung Memorial Hospital, Taipei, Chang Gung University College of Medicine, Taoyuan, Taiwan.
Received: Mar. 23, 2007; Accepted: Jul. 23, 2007
Correspondence to: Dr. Teresa Kit-Man Wong, Department of Anesthesiology, Chang Gung Memorial Hospital. No. 5, Fusing St., Gueishan Township, Taoyuan County 333, Taiwan (R.O.C.) Tel.: 886-3-3281200 ext. 8154: Fax: 886-3-3281200 ext. 8140; E-mail: kmwong@cgmh.org.tw

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 cmH_2O. An ETT one half-size larger was used to replace the first ETT if there was air leakage at 10 cmH_2O. 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.

Table 1. Reference Chart for ETT Size Selection

Length (cm)	Predicted uncuffed ETT size (mm)
52.5-67.5	4
> 67.5-82.5	4.5
> 82.5-97.5	5
> 97.5-112.5	5.5
> 112.5-127.5	6
> 127.5-142.5	6.5

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-

Table 2. Age and Gender Distribution of Patients

Age	Boys	Girls	Subtotal
1.5 mo-1 yr	36	8	44
> 1 yr-2 yr	81	10	91
> 2 yt-3 yr	59	12	71
> 3 yr-4 yr	40	14	54
> 4 yr-5 yr	29	14	43
> 5 yr-6 yr	24	9	33
Total	269	67	336

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[15] and > 112.5-127.5 cm,[30] 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 ($p = 0.308$).

Table 3. Reliability between Age Groups*

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

Groups were compared using chi-square analysis. p value = .94
*: Data are given as percentages (number of cases/total).

Table 4. Reliability between Length Groups*

Length (cm)	Correct tube size	Tube changed
52.5-67.5	73.3% (11/15)	26.7% (4/15)
> 67.5-82.5	75.9% (63/83)	24.1% (20/83)
> 82.5-97.5	85.0% (102/120)	15.0% (18/120)
> 97.5-112.5	86.4% (76/88)	13.6% (12/88)
> 112.5-127.5	83.3% (25/30)	16.7% (5/30)
Total	82.4% (277/336)	17.6% (59/336)

Groups were compared using chi-square analysis. p value = .308
*: Data are given as percentages (number of cases/total).

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

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.[16] 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+ 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

1. Koha BV, Jeon IS, Andre JM, MacKay I, Smith RM. Postintubation croup in children. Anesth Analg 1977;56:501-5.
2. Lee KW, Templeton JJ, Dougal RM. Tracheal tube size and postintubation croup in children. Anesthesiology 1980;53:325.
3. Litman RS, Keon TP. Postintubation croup in children. Anesthesiology 1991;75:1122-3.
4. Cole F. Selection of the proper endotracheal tube for a child. Anesthesiology 1953;14:506-7.
5. Corfield HMC. Orotracheal tubes and the metric system. Br J Anaeth 1963;35:34.
6. Steven JM, Cohen DE. Anesthesia equipment and monitoring. In: Motoyama EF, Davis PJ, eds. Anesthesia for Infants and Children. 5th ed. St. Louis: CV Mosby Company, 1990:217-56.
7. Fisher DM. Anesthesia equipment for pediatrics. In: Gregory GA, ed. Pediatric Anesthesia. 3rd ed. New York: Churchill Livingstone Inc, 1994:197-225.
8. Brown TCK, Fisk GC. Anesthesia for children. 2nd ed. London: Blackwell Scientific Publications, 1992:68-70.
9. Keep PJ, Manford MLM. Endotracheal tube sizes for children. Anaesthesia 1974;29:181-5.
10. Goldsmith JP, Karotkin EH. Resuscitation of the neonate. In: Diaz JH, ed. Perinatal Anesthesia and Critical Care. Philadelphia: WB Saunders Company, 1991:209-41.
11. Ferri LR, Cunningtham MJ. Determination of endotracheal tube size in pediatric patients. Arch Otolarngol Head Neck Surg 1992;118:448-9.
12. King B, Baker MD, Braitman LE, Seidl-Friedman J, Schreiner MS. Endotracheal tube selection in children: a comparison of four methods. Ann Emerg Med 1993;22:530-4.
13. Wang TK, Wu RS, Chen C, Chang TC, Hseih FS, Tan PP. Endotracheal tube size selection guidelines for Chinese children: prospective study of 533 cases. J Formos Med Assoc 1997;96:325-9.
14. Finholt DA, Henry DB, Raphaely RC. A “leak” test: a standard method for assessing tracheal tube fit in pediatric patients. Anesthesiology 1984;61:450.
15. Eckenhoff JE. Some anatomic considerations of the infant larynx influencing endotracheal anesthesia. Anesthesiology 1951;12:401-10.
16. Luten RC, Wears RL, Broselow J, Zaritsky A, Barnett TM, Lee T, Bailey A,Vally R, Brown R, Rosenthal B. Length-based endotracheal tube and emergency equipment in pediatrics. Ann Emerg Med 1992;21:900-4.
17. Davis D, Barbee L, Ririe D. Pediatric endotracheal tube selection: a comparison of age-based and height-based criteria. AANA J 1998;66:299-303.
18. Hofer CK, Ganter M, Tucci M, Klaghofer R, Zollinger A. How reliable is length-based determination of body weight and tracheal tube size in the paediatric age group? The Broselow tape reconsidered. Br J Anaesth 2002;88:283-5.
19. Deakers TW, Reynolds G, Stretton M, Newth CJ. Cuffed endotracheal tubes in pediatric intensive care. Pediatrics 1994;125:57-62.
20. Newth CJ, Rachman B, Patel N, Hammer J. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. J Pediatr 2004;144:333-7.
21. Dullenkopf A, Gerber AC, Weiss M. Fit and seal characteristics of a new paediatric tracheal tube with high volume-low pressure polyurethane cuff. Acta Anaesthesiol Scand 2005;49:232-7.

在華人兒童使用以身長爲基準的新公式來預測氣管內管尺寸之正確性

施明宏 鍾植楊 蘇百川 洪銚辰 黃樹欽 黃潔文

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。使用傳統以年紀爲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，設計了一個以身長爲基準的新公式：氣管內管內徑 (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爲基準的新公式計算。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值大或小於 1 mm 而需要換 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： 此以身長爲基準的新公式：氣管內管內徑 (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

長庚紀念醫院 台北院區 麻醉部 婦幼麻醉科；長庚大學 醫學院
受文日期：民國96年3月23日；接受刊載：民國96年7月23日
通訊作者：黃潔文醫師，長庚紀念醫院 麻醉部 婦幼麻醉科。桃園縣333龜山鄉復興街5號。
Tel.: (03)3281200轉8154; Fax: (03)3281200轉8140; E-mail: kmwong@cgmh.org.tw