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Do age-based formulae predict the appropriate endotracheal tube sizes in Japanese children?

Koichi Takita, Yuji Morimoto, Atsushi Okamura, and Osamu Kemmotsu

Department of Anesthesiology and Critical Care Medicine, Hokkaido University Graduate School of Medicine, Kita-15, Nishi-7, Kita-ku, Sappro 060-8638, Japan

Abstract
Purpose. Age-based formulae have been widely used to predict the appropriate size of the endotracheal tube (ETT) in children. These formulae are based on old data from Western countries. The current study was undertaken to assess the effectiveness of these formulae in Japanese children.
Methods. We reviewed data for the past 5 years from children (0–8 years of age) intubated orally with the regular uncuffed ETT or RAE type. The data included the child's age in years and months and the internal diameter (ID) of the ETT.
Results. Data from 1301 children were reviewed. The IDs of the most frequently used ETT were 3.0 mm for patients less than 1 month old, 3.5 mm for those 1 to 4 months old, 4.0 mm for those 5 to 17 months old, and 4.5 mm for those 18 to 23 months old. In children 2 to 8 years old, the ID of the most frequently used ETT was in accordance with the ID predicted by the formula ID (mm) = [age in years + 16]/4. However, the ID predicted by this formula applied to only 53.5% of our patients.
Conclusion. The age-based formula, ID (mm) = [age in years + 16]/4, is applicable to Japanese children. However, we recommend that three sizes be available before endotracheal intubation.

Key words Endotracheal tube · Children · Age

Introduction

In children, an endotracheal tube should be of sufficient size to allow easy ventilation, but small enough to allow a leak at 20 to 25 cm H_2O pressure to avoid postoperative croup [1]. It is important to predict the appropriate size of the uncuffed endotracheal tube before induction of anesthesia. The size of children's tracheas increases as they grow [2]. Age [3–5], height [5–7], weight [5], and the size of the little finger [8] have been used clinically to predict the appropriate size of uncuffed endotracheal tubes. Age-based formulae and guidelines are widely used. These formulae are based on old data obtained from Western children [3,4,6]. However, it has not been evaluated whether these formulae are also applicable to Japanese children of today. The current study was undertaken to assess the effectiveness of the modification of Cole's formula [3] (ID (mm) = [age in years + 16]/4) and Corfield's formula [4] (ID (mm) = [age in years + 18]/4) in Japanese children.

Materials and methods

The data were retrieved from the Hokkaido University Hospital Operating Room Data Management System (HODMS) [9], which currently contains the perioperative data from about 20 000 surgical patients. We reviewed data from children aged 0 to 10 years whose tracheas were intubated orally with regular uncuffed endotracheal tubes or the RAE type (Portex, Hythe, UK) in the operating rooms of Hokkaido University Hospital between 1 April 1994 and 31 March 1999. The data included date of birth, date of surgery, sex, height (cm), weight (kg), type of endotracheal tube, internal diameter (ID) (mm) of the endotracheal tube, and perioperative complications. The age in years and months was calculated from the date of birth and the date of surgery. Selection of the size of endotracheal tube was left to the discretion of the experienced Japanese Board-certified anesthesiologists in charge.

Spearman's regression analysis was used to calculate the correlation between age in years, height, weight, and ID of the uncuffed endotracheal tube.

Address correspondence to: K. Takita
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Results

During the study period, the tracheas of 1345 children aged 0 to 10 years were intubated orally with regular uncuffed endotracheal tubes or RAE tubes. There were no patients with major anomalies of the trachea or larynx. Forty-four patients aged 9 and 10 years intubated with uncuffed endotracheal tubes were excluded from this study, because the cuffed tubes were used in more than 50% of patients of this age group.

The correlation between age, height, weight, and ID of the uncuffed endotracheal tube used in the operating rooms was analyzed in 874 patients. Four hundred twenty-seven patients were excluded from this analysis because their height or weight was not recorded. The ID of the uncuffed endotracheal tubes was significantly correlated with the height, weight, and age expressed in years, as well as the age in months (Spearman's correlation coefficients $\rho = 0.897$, 0.881, 0.897, and 0.903, respectively; $P < 0.01$) (Fig. 1).

The distribution of uncuffed endotracheal tube size in different age groups is shown in Tables 1 and 2. In 627 patients aged 2 to 8 years, the effectiveness of the age-based formulae ID (mm) = [age in years + 16]/4 and ID (mm) = [age in years + 18]/4 was assessed. In patients aged 2, 4, 6, and 8 years, the ID of the most frequently used uncuffed endotracheal tubes matched the ID predicted by the formula ID = [age in years + 16]/4. Although the ID values calculated by this formula are not available for patients aged 3, 5, and 7 years, the ID of the most frequently used uncuffed tracheal tubes in these patients was 0.25 mm larger than the sizes calculated by this formula. The predicted endotracheal tube size was used in only 53.5% of patients. However, a selection of three tubes (one above and one below the predicted size) allowed appropriate intubation in 97.2% of the patients. Thirteen of 18 patients that these three tube sizes did not cover had no obvious factors that could alter the size of the trachea. In five patients, the height or weight was not within the range of the mean values ± standard deviation calculated from the patients of the same age. The ID of the uncuffed endotracheal tube calculated by the other formula (ID = [age in years + 18]/4) was larger than the ID of the most frequently used endotracheal tube in all age groups from 2 to 8 years. No major complications related to endotracheal intubation were recorded in the postoperative summaries of the anesthesia records.

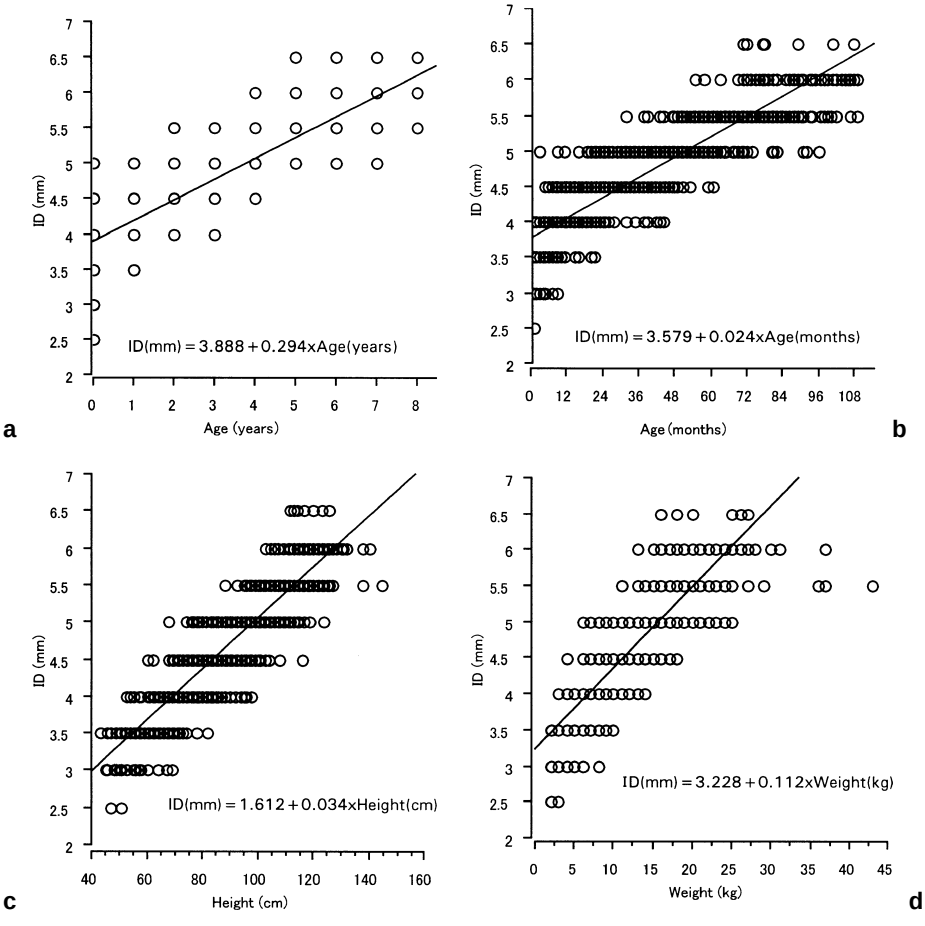

Fig. 1. Relationship and regression lines between internal diameter (ID) (mm) of the uncuffed endotracheal tube used in the operating room and age in years (**a**), age in months (**b**), height (**c**), and body weight (**d**)

Table 1. Distribution of internal diameter (ID) of the uncuffed endotracheal tubes used in patients 0–23 months old

	Age (mo)											
ID (mm)	0	1	2	3	4	5	6	7	8	9	10	11
2.5	1		1									
3	14	11	14	5	3		1	1	4			
3.5	2	15	16	25	32	37	16	12	11	9	11	2
4		1	3	8	16	43	22	17	15	16	13	13
4.5				1	2	1	6	2	4	3	5	4
5									1			1

	Age (mo)											
ID (mm)	12	13	14	15	16	17	18	19	20	21	22	23
2.5												
3												
3.5	1			2					2			
4	13	15	5	7	4	10	7	7	12	3	5	3
4.5	8	6	7	6	4	6	13	32	15	9	7	6
5	1						1	6	5	2	3	3

Table 2. Distribution of ID of the uncuffed endotracheal tubes used in patients 2–8 years old

	Age (yr)						
ID (mm)	2	3	4	5	6	7	8
3.5							
4	17	6					
4.5	84	55	10		1		
5	33	69	62	37	7	4	
5.5	1	18	43	47	37	11	8
6			2	10	20	19	18
6.5				2	2	2	2
7							

Discussion

The present retrospective analysis shows that height, weight, age in years, and age in months correlated well with the ID of the uncuffed endotracheal tube used by anesthesiologists in patients aged 0 to 8 years, and that the age-based formula, ID = (age in years + 16)/4, is appropriate for patients aged 2 to 8 years. Previous studies [7,10–12] show that age, height, and weight are good predictors of the appropriate endotracheal tube size in Japanese children. Some authors have proposed formulae and nomograms to predict the appropriate uncuffed tracheal tube size for Japanese children [7,10,11]. However, most of them are complicated and difficult to memorize. Accordingly, the age-based formulae based on the old data from Western countries [3,4] (ID = [age in years + 16]/4 and ID = [age in years + 18]/4) are widely used for Japanese children aged 2 to 10 years. Although it has been shown that these age-based formulae are reliable and acceptable for Western children today [13,14], it has not been evaluated whether these formulae are applicable to Japanese children today. Our results indicate that the age-based formula, ID = [age in years + 16]/4, is applicable to Japanese children 2 to 8 years of age. Nevertheless, three tube sizes should be available for each case before tracheal intubation is attempted. A range of three tubes around the predicted tube size in the age group from 2 to 8 years covered 97.2% of the patients, whereas having one size predicted by the formula allowed appropriate intubation in only 53.5% of the patients.

There are some potential errors in this retrospective study. Were the selected tube sizes the most appropriate for all patients? Did the anesthesiologists select the tube size on the basis of these well-known age-based formulae? Our anesthesiologists usually select a size that allows a small gas leak at peak inflation pressures of 20 to 25 cm H_2O. No perioperative complications re-

lated to inappropriate endotracheal tube size, including ventilation with difficulty and severe postoperative croup, were reported. This suggests that most of the endotracheal tube sizes selected by experienced anesthesiologists in the present study were appropriate in the clinical setting. However, the lack of a uniform definition of the most appropriate tube size under constant conditions of depth of anesthesia and degree of muscle relaxation is certainly a pitfall of the present retrospective study. Accordingly, for more reliable evaluation of the effectiveness of these age-based formulae in Japanese children, prospective studies with a uniform definition of the appropriate tube size are needed.

In conclusion, the age-based formula, ID = [age in years + 16]/4, is reliable and appropriate for Japanese children 2 to 8 years of age who require endotracheal intubation. Before endotracheal intubation is attempted, tubes of three sizes should be available: the predicted size, one with an ID 0.5 mm less than the predicted size, and one with an ID 0.5 mm greater than the predicted size.

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