Factors influencing the accuracy of ETT size prediction in children with CHD: a pilot study

R F Soenarto, H Kusuma*
Department of Anesthesiology and Intensive Care, Cipto Mangunkusumo General Hospital, Universitas Indonesia, Jakarta, Indonesia
E-mail: kuskushendrahe@gmail.com

Abstract. Induction and intubation for pediatric patients with congenital heart defects (CHD) should be conducted with careful measures to avoid any complications due to anesthetic drugs. Proper endotracheal tube (ETT) size is essential to avoid reintubation. The aim of this study is to analyze factors affecting the accuracy of uncuffed ETT size prediction in paediatrics with CHD. This observational-analytic study included seventeen patients aged 0-8 years with CHD underwent general anesthesia with tracheal intubation. Subjects were classified as cyanotic or acyanotic heart disease. The ETT size was predicted by Cole’s formula. The accuracy of prediction was analyzed according to age, body weight, height and type of CHD. The prediction of ETT size was accurate in 53% of the subjects. The prediction was inaccurate in 63% of cyanotic subjects, while only 16.7% of acyanotic subjects. Univariate analysis for all variables showed there was no significant factor to affect the accuracy of ETT size prediction. The smallest p value was subject’s height. Height has a 69.8% affecting factor to predict the accurate ETT size. Thus, age, body weight, height and type of CHD are not statistically significant factors to affect the accuracy of ETT size prediction. But, height gives a better prediction to the accuracy of ETT size.

1. Introduction
Pediatric patients with congenital heart defects (CHD) often require anesthesia, either for diagnosis or therapy. Induction and intubation for this population should be conducted with careful measures to avoid any complications due to anesthetic drugs. Thus, proper endotracheal tube (ETT) size is essential to avoid reintubation.

The prediction of tube size is often done by using Cole’s formula based on patient’s age [1]. However, this technique is often incorrect so that reintubation happens. Pediatric with CHD mostly failed to thrive so that their anatomy are not always appropriate for their age. Many of these children are smaller, shorter and have less weight than normal children [2]. This study aimed to measure factors influencing the prediction of tube size in children with CHD, such as age, body weight, height and type of CHD.

2. Methods
This pilot study was an observational-analytic non interventional study, with 17 subjects enrolled. All subjects were Malay patients aged 0-8 year with congenital heart diseases underwent general anesthesia. Subjects were classified as cyanotic or acyanotic heart disease. The subjects’ body weight and height were classified into “normal” or “not normal” according to the WHO growth chart (for 0-5 years old) and CDC growth chart (for above 5 years old) [3].
For all subjects ETT sizes were predicted by the Cole formula. All ETT were of “uncuffed” type. We would exclude subjects if there were difficulty to intubate (Cormack Lehane score 3-4). The criteria of “proper size” were defined as follows: after intubation, ventilation was managed manually with 6-12 L/min of oxygen to achieve inspiratory pressure 15-25 cmH2O. If there was a minimal leakage heard and the ventilation bag expanded more than a half from its capacity volume, the ETT size was defined “proper”. If necessary, the improper ETT size should removed and replaced with another ETT.

3. Results
This pilot study was carried on at the operating theatre of Integrated Cardiac Services, Cipto Mangunkusumo Hospital in Jakarta. Most patients (70%) were 0 to 2 years old. A proportion of 76.5% (13 subjects) were classified as underweight, 82.4% (14 subjects) were short to their age and 64.7% (11 subjects) were cyanotic patients. There was no difficult airway found.

Table 1 is the demographic data of the subjects. Majority of the subjects were underweight and short in height. Nutritional status was equal, between normal and undernourished.

| Characteristics | Total N (%) |
|----------------|-------------|
| Age (years), $\chi \pm SD$ | 1.97 $\pm$ 1.32 |
| <1, n (%) | 3 (11.8) |
| 1 | 6 (35.3) |
| 2 | 4 (23.5) |
| 3 | 1 (5.9) |
| 4 | 2 (11.8) |
| 5 | 1 (5.9) |
| Sex, n (%) | |
| Male | 7 (41.2) |
| Female | 10 (58.8) |
| Weight (kg) | 8.43 $\pm$ 2.73 |
| Normal | 4 (23.5) |
| Underweight | 3 (17.6) |
| Height (cm) | 75.88 $\pm$ 13.69 |
| Normal | 13 (76.5) |
| Short stature | 14 (82.4) |
| Nutritional status, n (%) | |
| Normal | 8 (47.1) |
| Undernourished | 9 (52.9) |
| Congenital heart disease, n (%) | |
| Cyanotic | 11 (64.7) |
| Acyanotic | 6 (35.3) |

The accuracy of Cole’s formula was 53% while 47% subjects got improper ETT size. Two patients needed reintubation with bigger size ETT. However, bivariate analysis showed that all parameters were not significant to influence the accuracy of the use of Cole’s prediction formula (p >0.05) as seen in table 2.

Types of CHD, although is not significant statistically, but showed difference as seen in table 3. Since height has the smallest p value (table 2), we did a correlation test. It showed that height had the biggest correlation.

Then we continued to perform linear regression model of this data. Subjects’ height seems to have the biggest $R^2$ value. In other words, height is more influencing for accuracy in predicting ETT size.

4. Discussions
Unlike what we observed in daily practice, the statistical analysis showed none of age, weight, height and type of CHD affecting the accuracy in predicting ETT size. This is quite disappointing, because
the frequency of inaccurate ETT size is actually high in our practice and is not met with the need for efficacy. We assume that this insignificance was due to the small amount of subjects. It is reasonable since this was a pilot study. But, this result showed that a proper full-scale study on this topic is feasible to do. And it is essential to run a further study, as some results gave promising direction for a better anesthesia practice in the future.

**Table 2. Factors affecting the accuracy of ETT size prediction.**

|              | p value | Statistical Analysis     |
|--------------|---------|--------------------------|
| Age          | 0.139   | Mann-Whitney test        |
| Weight       | 0.144   | Independent T test       |
| Height       | 0.093   | Mann-Whitney test        |
| CHD types    | 0.131   | Fischer test             |

**Figure 1.** The proportion between accurate & inaccurate in predicting ETT size.

**Table 3. Accuracy of ETT size prediction between types of CHD.**

| Types of CHD | Accuracy | Total |
|--------------|----------|-------|
|              | Unproper | Proper |
| Acyanotic    | 1 (16.7%)| 5 (83.3%)| 6 |
| Cyanotic     | 7 (63.6%)| 4 (36.4%)| 11 |
| Total        | 8        | 9      | 17 |

Table 2 showed that although type of CHD was also statistically not a significant factor of the accuracy of prediction, cyanotic patients showed a bigger proportion of improper ETT size (63.6%) compared with acyanotic patients (16.7%). This is clinically important, since most of cyanotic CHD patients have worse conditions and need more caution. Most of the cyanotic patients are very weak, small, cranky and sometimes come with unstable hemodynamic [4]. Using improper ETT size for intubation is inconvenient, not only for anesthesiologists but also for patients’ safety. Oversize ETT makes longer intubation time and could lead to hemodynamic instability [4-6]. Undersize ETT gives improper ventilation management. The need for reintubation is also an unfavourable period especially in cyanotic patients.

Based upon the p value, we tried to analyze the subjects’ height, which has the smallest p value. By using correlation test we found that height has the strongest correlation to affect the accuracy of ETT size prediction. With the linear regression model, height has almost 70% affecting factor for accuracy in predicting ETT size.
Figure 2. The proportion of accuracy in predicting ETT size, between cyanotic and acyanotic CHD patients.

Table 4. Correlation between age, weight and height with proper size of ETT.

|        | R   | p value | Correlation test |
|--------|-----|---------|------------------|
| Age    | 0.731| 0.001   | Spearman         |
| Weight | 0.843| 0.000   | Pearson          |
| Height | 0.847| 0.000   | Spearman         |

Table 5. The linear regression model.

| Linear Regression Model | R² |
|-------------------------|----|
| Age Predicted ETT size (mm)= 4.1 + 2.7 x age (year) | 0.437 |
| Weight Predicted ETT size (mm)= 3.3 + 0.16 x BW (kg) | 0.691 |
| Height Predicted ETT size (mm)= 2.2 + 0.03 x BH (cm) | 0.698 |

5. Conclusions
Age, body weight, height and types of CHD are not proven to be factors affecting the accuracy of ETT size prediction formula. Prediction of ETT size is less accurate in cyanotic patients. There were suspicious results that height might affect this accuracy. We need a further full scale study with bigger sample size to prove it, and to create a new formula to predict ETT size in children with CHD.

6. References
[1] Cole F 1957 *Omaha* Pediatric formulas for the anesthesiologist *Arch. Pediatr. Adolesc. Med.* 94 6 p 672
[2] Wijaya A A and Soenarto R F 2012 Anestesi Pediatrik *Buku Ajar Anestesiologi I*st ed. (Jakarta: Departemen Anestesiologi dan Terapi Intensif) pp 375–96
[3] WHO Growth Chart 2018 IDAI available at http://www.idai.or.id/professional-resources/growth-chart/kuva-pertumbuhan-who
[4] Chumpathon S, Muangman S et al 2012 Comparison of age-based and height-based formula for tracheal tube size in cardiac children *J. Med. Assoc. Thai.* 95 4 p 6
[5] Bunhumongkol N and Pipanmekaporn T 2010 Prediction of endotracheal tube size in children with failure to thrive, who underwent cardiac surgery *Chiang. Mai. Med. J.* 49 2 pp 49–52
[6] Ohashi N, Imai H, Seino Y and Baba H 2017 Pediatric patients with high pulmonary arterial pressure in congenital heart disease have increased tracheal diameters measured by computed tomography *J. Cardiothorac. Vasc. Anesth.* available at http://linkinghub.elsevier.com/retrieve/pii/S1053077017309898