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Original Research Article

Estimation of Appropriate Size Endotracheal Tube for Anaesthetic Intubation in Children

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Abstract

Background: Endotracheal intubation is a common procedure for airway management and general anaesthesia in children. A selection of correct size endotracheal tube is one of the essential prerequisites for successful intubation, especially in children. In this study, we wanted to determine the appropriate size of cuffed endotracheal tube for anaesthetic intubation for different age subgroups of children between 4 and 12 years of age.

Methods: This is an observational retrospective study conducted in the Government Medical College, Ernakulam, Kerala, over a period of 6 months from June 2021 to December 2021, among children between 4 and 12 years (completed 12 years).

Results: The estimated appropriate size of cuffed ETT in 4 - 5 years age group is 4.5/5 (rarely 4), in 5 - 6 years age group is 5/4.5 (rarely 5.5), in 6 - 7 years age group is 5/5.5 (rarely 4.5), in 7- 8 years age group is 5/5.5, in 8 - 9 years age group is 5/5.5, in 9 - 10 years age group is 5.5/5 (rarely 6), in 10 - 11 years age group is 5.5/6 (rarely 5), in 11 - 12 years age group is 5.5/6 (rarely 5/6.5), and in 12 - 13 years age group is 6/6.5 (rarely 5.5/7). If a wider age category considered the ETT size requirement in different age group are 4 - 6 years – 5/4.5, 6 - 10 years – 5/5.5, 10 - 12 years – 5.5/6, 12 - 13 years – 6/6.5. On rare occasions, sizes smaller by 0.5 mm may be required occasionally and has to be anticipated. For cuffed ETT size smaller by 0.5 – 1 mm it can be derived by formula (Age + 4)/4.

Conclusion: Since children need varying sizes of ETT and due to requirement of ETT sizes variable as anticipated from different formulas or recommended charts, a wide array of ETT sizes should be readily available in paediatric operation theatre.

Keywords: Appropriate Size, Endotracheal Tube, Anaesthetic Intubation, Children.

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Introduction

Endotracheal intubation is a common procedure for airway management and general anaesthesia in children. The child is not a miniature adult. The children have a narrower trachea and need a smaller endotracheal tube, and since they have a rapid growth profile, each age subgroups of children need different endotracheal tube sizes.

The endotracheal tubes are available in various sizes of internal diameters with increasing internal diameter of 0.5 each (2.5, 3, 3.5, 5, 5.5, etc.)

The approximate expected size of endotracheal tube required for endotracheal intubation should be known and kept ready during induction of anaesthesia. Due to varying sizes of endotracheal tube required in each sub age group of children, selection of appropriate size of endotracheal tube required for intubation should be known. A selection of correct size endotracheal tube is one of the essential prerequisites for successful intubation especially in children, as selection of an inappropriate size endotracheal tube results in unsuccessful intubation, repeated intubation, trauma to airway, leaks etc. Also, in a logistic point of view, storing and procurement of appropriate size endotracheal tube (commonly used, least commonly used) is important.

The somatic growth of children follows different patterns during each subgroup. There is a rapid exponential growth during first few years of life which slows down till early adolescence, from where again an exponential somatic growth occurs during adolescence.

The commonest formula for selecting appropriate size of endotracheal tube in paediatric age group is (Age + 4)/4. However, this formula is recommended for uncuffed endotracheal tubes and often observed that it is not applicable especially when cuffed endotracheal tubes are used and there is discrepancy between tubes when selected using calculated formula with actual size that needs to be used. Hence, a study to estimate the appropriate size of endotracheal tube for intubation will aid in anticipation of appropriate size of ETT that has to be selected during general anaesthesia in children.

Objectives

To determine the appropriate size of cuffed endotracheal tube for anaesthetic intubation for different age subgroups of children between 4 - 12 years i.e., 4 - 5 years, 5 - 6 years, 11 - 12 years, 12 - 13 years.

Methods

This is an observational retrospective study conducted in the Government Medical College, Ernakulam, Kerala, over a period of 6 months from June 2021 to December 2021, among children between 4 and 12 years (completed 12 years).

Exclusion Criteria

Children with obesity, malnutrition, difficulty in mouth opening.

Children who had difficult intubation.

Laryngeal oedema, laryngeal inlet obstruction, airway abnormalities

Emergency surgery.

Study Procedure

Anaesthesia records (Registers) during the last 10 years (June 2011 to June 2021), are reviewed and the children with ages between 4 - 12 years who underwent general anaesthesia with endotracheal intubation were selected for study. The age, gender, endotracheal tube size used (under direct laryngoscopy cuffed/non-cuffed) and difficult intubation were observed and recorded. The ages are categorized as 4 to 5 years, 5 to 6 years, 6 to 7 years, 11 to 12 years and above 12 years, below 13 years.

Statistical Analysis

The data obtained from the study was entered in MS Excel and further analysis was done using Statistical Package for Social Sciences (SPSS). Results were presented as tables.

Results

A total number of 314 cases were selected for the study. Of these, 154 were female children and 160 male children.

Requirement of cuffed endotracheal tubes in different age groups is as follows:

Between 4 - 5 years of age, (above 4 years below 5 years) there were a of total number of 30 cases. ETT size 4.5 was required in 15 (50 %), size 5 was required in 11 (36.6 %), size 4 was required in 4 children (13.33 %). 86.6 % required either size 4.5 or 5. Commonest used was 4.5 size (50 %).

In 5 - 6 years of age, out of total number of 48 cases, 34 (70.83 %) required size 5, 11 (22.9 %) required size 4.5 and 3 (6.25 %) required size 5.5. (93.7 %) required size either 5 or 4.5. Commonest size used was size 5 (70.83 %).

In 6 - 7 years (above 6 years and below 7 years), out of 45 children, 35 (77.7 %) required size 5, 7 (15.55 %) required size 5.5 and 3 (6.66 %) required size 4.5.

93.2 % of cases required either 5 or 5.5 commonest size used was size 5 (77.7 %).

Between7 – 8-year age group, 22 out of 35 (62.85 %) required size 5 whereas 13 out of 35 (37.14 %) required size 5.5. 100 % required either size 5 or 5.5. Commonest ETT size used was 5 (62.85 %).

In 8 - 9 years, 16 out of 30 (53.33 %) required size 5 whereas 14 out of 30 (46.66 %) required size 5.5. 100 % required either size 5 or 5.5.

In 9 - 10 years, the ETT size required were size 5.5 for 16 out of 33 (48.48 %), size 5 for 12 out of 33 (36.36 %) and size 6 for 6 out of 33 (15.15 %). 84.8 % required either size 5.5 or 5.

In 10 - 11 years, size 5.5 was required for 15 out of 32 (46.87 %) size 6 for 11 out of 32 (34.37 %) and size 5 for 6 out of 32 (18.75 %). 81.3 % required either size 5.5 or 6.

In 11 - 12 years, size 5.5 was required for 12 out of 29 (41.37 %), size 6 for 10 out of 29. (34.48 %) size 5 for 4 out of 29 (13.79 %) and size 6.5 for 3 out of 29 (10.3 %). 75.85 %required size 5.5 or 6.

In 12 - 13 years size 6was required for 15 out of 32 (46.87 %), size 6.5 for 10 out of 32 (31.25 %), size 5.5 for 6 out of 32 (18.75 %) and size 7 for 1 out of 32 (3.1 %). 78.12 % required either size 6 or 6.5.

Table 1: Number of Children in Each Age Group – Vs Requirement of ETT Size

Total		**Endotracheal tube size 4 to 7 mm**						
Age	**Number(n)**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**
4 - 5 years.	30	4	15	11	0	0	0	0
5 - 6 years.	48	0	11	34	3	0	0	0
6 - 7 years.	45	0	3	35	7	0	0	0
7 - 8 years.	35	0	0	22	13	0	0	0
8 - 9 years.	30	0	0	16	14	0	0	0
9 - 10 years.	33	0	0	12	16	5	0	0
10 - 11 years.	32	0	0	6	15	11	0	0
11 - 12 years.	29	0	0	4	12	10	3	0
12 - 13 years.	32	0	0	0	6	15	10	1
Total	**314**							

Table 2: Percentage of Requirement of ETT Size in Age Groups

Age	**Number(n)**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**
4 - 5 years	30	13.33%	50%	36.6%	0 %	0%	0%	0%
5 - 6 years	48	0%	22.9%	70.83%	6.25%	0%	0%	0%
6 - 7 years	45	0%	6.66%	77.7 %	15.55%	0%	0 %	0%

7 - 8 years	35	0%	0%	62.85%	37.14%	0	0	0
8 - 9 years	30	0	0	53.33%	46.66%	0	0	0
9 - 10 years	33	0	0	36.36%	48.48%	15.15 %	0	0
10 - 11 years	32	0	0	18.75%	46.87%	34.37%	0	0
11 - 12 years	29	0	0	13.79	41.37	34.481	10.3%	0
12 - 13 years	32	0	0	0	18.75%	46.87	31.25%	3.1%

Table 3: Estimated/Anticipated Size of ETT (Cuffed) in Different Age Groups

Age	Frequency/ Percentage ETT Size (Cuffed) Used	ETT Size (Cuffed) Most Frequent/Higher Percentage	ETT Size Less Frequent (Less Percent)
4 - 5 years.	4.5 – 50% 5 – 36.6% 4 – 13.33%	4.5/5 – 86.6%	4 - 13.3%
5 - 6 years.	5 – 70.8 % 4.5 – 22.9% 5.5 – 6%	5/4.5 – 93.7%	5.5 in 6.25%
6 - 7 years.	5 – 77.7% 5.5 – 15.5% 4.5 – 6.6%	5/5.5 – 93.2%	4.5 - 6.6%
7 - 8 years.	5 – 62.8 5.5 – 37.14	5/5.5 – 100%	-
8 - 9 years.	5 – 53.3% 5.5 – 46.6%	5/5.5 – 100%	-
9 - 10 years.	5.5 – 48.48% 5 – 36.36% 6 – 15.15%	5.5/5 – 84.84%	6 - 15%
10 - 11 years	5.5 – 46.87% 6 – 34.37% 5 – 18.75%	5.5/6 – 81.2%	5 - 18.7%
11 - 12 years	5.5 – 41.37% 6 – 34.48% 5 – 13.34% 6.5 – 10.34%	5.5/6 – 75.85%	5 - 13.4% 6.5 - 10.3%
12 - 13 years	6 – 46.87% 6.5 – 31.2% 5.5 – 18.75% 7 – 3.1%	6/6.5 – 78%	5.5 - 18.75% 7 - 3.1%

Table 4: Estimated/Anticipated Appropriate Size of ETT (Cuffed) in Wider Age Groups

Age	Total No	ETT size no: & percent	ETT size most frequent (higher percent)	Categories ETT size of less frequent (percent)
4 - 5 years.	30	4.5 – 15 (50%) 5 - 11 (36.6%) 4 – 4 (13.3%)	4.5/5 = 86.6%	4 (13.3%)
5 - 6 years.	48	5-34 (70.83%) 4.5-11 (22.9%) 5.5-3 (6.25%)	5/4.5 = 93.7%	5.5 - 6.3%

6 - 7 years.	45	5 – 35 (77.7%) 5.5 – 7 (15.5%) 4.5 – 6.6%	5/5.5 93.2%	4.5 - 6.6%
7 - 10 years.	98	5 – 50 (51 %) 5.5 – 43 (43.8 %) 6 – 5 (5.2 %)	5/5.5 94.8 %	6 -5.2%
10 - 12 years.	61	5.5 – 27(44.26%) 6 – 21 (34%) 5 – 10 (16%) 6.5 – 3 4.9%	5.5/6 = 78.4%	5 = 16% 6.5 – 4.9%
12 - 13 years.	32	6-15 (46.8%) 6.5 – 10 (31.25) 5.5-6 (18.75%) 7-1 (3.1%)	6/6.5 78%	5.5 = 18.75% 7 – 3.1%

Table 5: Estimated Appropriate Size of ETT (Cuffed) in Wider Age Group Categories

Age Group	Total No	ETT Size No. (Percent)	ETT Size Most Frequent (Higher Percent)	ETT Size Less Frequent (Percent)
4 - 6 years.	78	4.5 - 26 (33.3%) 5 - 45 (57.6%) 4 - 4 (5.1%) 5.5 - 3 (3.8%)	90.9% required size 5/4.5	Smaller size (4) in 5.17% & larger size in (5.5) in 3.8%
6 - 10 years.	143	5 - 85 (59.4%) 5.5 - 50 (34.96%) 4.5 - 3(2%) 6 - 5(3.4%)	94.3% required size 5/5.5	2% required of smaller size (4.5) or 3.4% required larger size – 5
10 - 12 years.	61	5.5 - 27 (44.2%) 6 - 21 (34.4%) 5 - 10 (16%) 6.5 - 3 (4.9%)	78.6% required 5.5/6	16 % required smaller (5) and 4.9% - larger (6.5)
12 - 13 years.	32	6 - 15 (46.87%) 6.5 - 10 (31.25%) 5.5 - 6 (18.75%) 7 - 1 (3.1%)	78 % required 6/6.5	18.7% required smaller (5.5) and 3.1% required larger 7 size ETT

Table 6: Comparison of ETT Sizes with Formula (Age+4)/*4*

(Completed Age Years. + 4/4)		No. Percentage Corresponding	Remarks
4 - 5 yrs.	4/4+4 = 5	11/30 = (36.6%)	63.33% (intubated with a lesser size (4/4.5)
5 - 6 yrs.	5/4+4 = 5 (approximate)	34/48 = (70.83%)	22.9% needed ETT size smaller by (0.5) 6 % required larger
6 - 7 yrs.	6/4+4 = 5.5	7/4 = (15.55%)	77.7% intubated with 0.5 mm lesser size tube. 1mm lesser size for 6.6%
7 - 8 yrs.	7/4 + 4 = 5.5 (approximate)	13/35 = (37.14%)	62.85% intubated with 0.5 lesser size (5 size)
8 - 9 yrs.	8/4+ 4 = 6	0/30 = (0%)	All patients required intubation

			with lesser size
9 - 10 yrs.	9/4+4 = 6 (approximate)	5/33 = (15.15%)	74.8% required intubation with lesser size ETT (5/5.5)
10 - 11 yrs.	10/4 + 4 = 6.5	0/32 = (0%)	All (100%) required intubation with lesser size (6/5.5/5)
11 - 12 yrs.	11/4+4 = 6.5 (approximate)	3/29 = (10.3%)	89% required intubation with lesser size (6/5.5/5)
12 - 13 yrs.	12/4+4 = 7	1/32 = (3.11%)	97% required intubation with lesser size ETT (6.5/6/5.5)

Discussion

In 1957, Dr. Cole (Dr. Frank Cole M.D - 1909-1982) proposed a formula to estimate the best endotracheal tube size for a paediatric patent. Modification of his formula is size of ETT (I.D) (uncuffed) = (Age + 4)/4 became popular and is widely used.

Another formula (Age + 4)/4 was used by Henry H. Khine et al. [1] for children below 8 years and was found appropriate for cuffed tubes in 99 %, and uncuffed tubes selected by Coles formula in 77 %.

This study also concluded that cuffed ETT have advantages such as avoidance of repeated laryngoscopy, use of low fresh gas flow and reduction of concentration of anaesthetic gases detectable in operating room.

Another study by Duracher et al [2] showed that size of ETT predicted using the Khine formula, underestimated the size of endotracheal tube by 0.5 mm.

A formula (Age + 3.5)/4 was generated based on this. A study by Ria Manimalethu et al. [3] concluded that Duracher formula is superior to Khine and Cole formula when selecting the appropriate size of cuffed ETT.

A Japanese study by K. Shiroyame et al. [4] concluded that Cole's formula cannot accurately estimate the appropriate cuffed endotracheal tube size.

In a study by Saowa Park et al. [5] to find out the effectiveness of age based formula to predict ETT size in cardiac patients, it was concluded that age based formula is applicable in age group 2 - 7 years old, and is less appropriate in older age group.

There are many variables in predicting size of ETT size such an age, weight, height etc. Based on these variables, Adriana et al. reviewed the studies in literature. [6] There are about 22 published formulas available in literatures to estimate the appropriate endotracheal tube size for paediatric patients. 12 age-based formulas for tubes without cuff, 4 height based formula as for tubes without cuff and 3 age based formulas for cuffed endotracheal tubes. [7]

Ultrasound can also be used on a guideline for predicting ETT size in children. [8] A study by Matula Tareerath et al. [9] concluded that in most patients aged 2 - 8 years for tonsillectomy, the size of cuffed preformed ETT could be predicted by Motoyama formula (Age + 3)/4. An exception was a small group of children who needed a smaller size tube (by 0.5mm). A review article by Neeraj Bhardwaj [10] narrates number of advantages for cuffed ETT such as lower use of fresh gas flow, reduced air pollution, reduced risk of aspiration and avoidance of repeated laryngoscopies. The article also reviews the recommended ETT size in age group 0 - 5 years using Khine, Motoyama and Salgo etal formula.

Charles J. Cole (Miller's Anaesthesia 7th Edition) [11] recommend cuffed ETT size 4.5/5 at 2 years of age, 5/5.5 at 6 - 7 years of age and 6/6.5 at 10 years of age.

This study was aimed at estimating the appropriate size of endotracheal tube for

anaesthetic intubation in children. Children in age group 4 - 12 groups who had endotracheal intubation for anaesthesia were selected and ETT sizes (cuffed) were analysed retrospectively.

Age groups categorized were as 4 - 5 years, (age at or above 4 years, but below 5 years) 5 - 6 years, 6 - 7 years – etc till 12 years (above 12 and below 13 years). A total of 314 cases were taken for study. The number under each age category with respective sizes of ETT size plotted as numbers as percentages (tables 1, 2). Also, a comparison of ETT sizes was compared with size that obtained from formula (Age + 4)/4 was also done (Table 6).

Most frequently and less frequently used ETT sizes are also plotted (Tables 3, 4, 5). The most frequent size of ETT used were 4 - 5 years (4.5/5), 5 - 6 years (4.5/5), 6 - 7 years (5/5.5), 7 - 8 years (5/5.5), 8 - 9 years (5/5.5), 9 - 10 years (5.5/5), 10 - 11 years (5.5/6), 11 - 12 years (5.5/6) and 12 - 13 years (6/6.5).

ETT smaller size or larger size was used with lesser frequency as plotted in table - 3. When the age groups were categorized on wider ranges, it has been observed that sizes 4.5/5 were the most common in age 4 - 6 years and 5/5.5 size between 6 - 10 years. The ETT size shifted to a higher size 5.5/6/6.5 after 10 years.

One of the salient features of the study was the observation that in the age group between 6 and 10 years – 5/5.5 ETT was required and ETT size did not increase much. Childhood is a period of rapid somatic growth. However, this growth does not follow a uniform linear pattern throughout childhood. The brain growth and head circumference growth are most prominent in first 4 years of life and then the velocity of growth reduces. During first 3 - 4 years of life, children have rapid somatic growth, which attains a lesser growth velocity till start of adolescence (10 - 12 years) from where again a rapid somatic growth occurs during adolescence. This pattern of somatic growth with corresponding growth in airways and lungs may explain the observation that in a wide age group, 6 - 10 years need an ETT size 5 or 5.5 (table 4,5) without much gradation in size of ETT. However, there is more frequency of size 5 ETT towards age 6 and more use of size 5.5 towards age 10. After 9 - 10 years, the ETT size shift to 6/6.5 range.

There are many formulas conventionally used and available in literature to aid easy calculation of anticipated size of ETT. The commonest formula (modified) Cole's (age +4)/4is applicable mostly for uncuffed ETT. A size 1 mm less (Age + 3)/4 have been recommended by Khine et al. in studies. Duracher et al. [2] recommended size 0.5 mm lesser for cuffed ETT (Age + 3.5)/4. The present study is in concordance with above studies.

Study by Saowa Park et. al. [5] concluded that age based formulas were applicable only for 2 - 7 years and was not applicable for older age groups. The present study also points to the same as we find that there is not much gradation in ETT size between 6 - 10 years.

This study compared the ETT size value obtained by formula (Age + 4)/4with the actual ETT size (table - 6). Except in age group 5 - 6 years, the ETT size requirement was lesser size by (0.5 - 1mm). In age group 8 - 9 years, 10 - 11 years and 12 - 13 years, 97-100 % required lesser sized ETT by 0.5 - 1mm.

A study by Shiroyama et al. found that Cole's formula is less appropriate to find cuffed ETT size, which is in concordance with present study.

The conventional formulas derive only a single value of ETT size and due to interpersonal variations and other anthropological variations within normal growth pattern such as height, weight, sex, or racial or anatomical variations, children of same age group may need different ETT

sizes. Also, these formulas derive decimals (For eg: at age 5, 7, 9 etc.) which need approximation.

Hence, estimation of appropriate size ETT in each age group has relevance. This study could ascertain most frequent ETT size in each subgroup, (4 - 5 years, 5 - 6 years etc.) Table 3 and also at wider age group categories (table 4 and 5).

In some age subgroup, it has been found that smaller frequency of children required a smaller or larger ETT size, as compared to most frequently used size. Malnutrition, obesity and other growth anomalies have been excluded from the study. This could be explained by other variables that could affect the ETT size such as anthropological variations (Height, weight within normal growth curve), minor anatomical differences or sex. In each age group of 1 year interval, age correction to months were not obtained in the study (eg: 4 years 2-month, 5 year 6 month etc.). Due to rapid growth profile, difference within each sub-group at each extreme. (eg. 5-year 1 month and 5 year 11 month) could also be a reason for this finding of a lesser percent of children requiring small/large size tubes. This forms a limitation of the study.

Sex differences in each subgroup of age has not been analysed in this study, which also forms a limitation of this study.

Conclusions

The estimated appropriate size of cuffed ETT in 4 - 5 years age group is 4.5/5 (rarely 4), in 5 - 6 years age group is 5/4.5 (rarely 5.5), in 6 - 7 years age group is 5/5.5 (rarely 4.5), in 7 - 8 years age group is 5/5.5, in 8 - 9 years age group is 5/5.5, in 9 - 10 years age group is 5.5/5 (rarely 6), in 10 - 11 years age group is 5.5/6 (rarely 5), in 11 - 12 years age group is 5.5/6 (rarely 5/6.5), and in 12 - 13 years age group is 6/6.5 (rarely 5.5/7). If a wider age category considered the ETT size requirement in different age group are 4 - 6 years – 5/4.5, 6 - 10 years – 5/5.5, 10 - 12 years – 5.5/6, 12 - 13 years – 6/6.5. On rare occasions, sizes smaller by 0.5 mm may require occasionally and has to be anticipated. For cuffed ETT, size smaller by 0.5 – 1 mm should be used, and it can be derived by formula (Age+4)/4. Since children need varying sizes of ETT and due to requirement of ETT sizes varies as anticipated from different formulas or recommended charts, a wide array of ETT sizes should be readily available in paediatric operation theatre.

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