ECUATORIAN JOURNAL OF PEDIATRICS
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ORIGINAL RESEARCH

Predictive variables for endotracheal tube size in pediatric patients in the intensive care unit.

Adriana Evelyn Rubio Ramírez *[1] **Paul Escalante Canto**[1]
https://orcid.org/0000-0002-8189-0206

1. Postgraduate department of pediatrics, school of medicine, faculty of medical sciences, Universidad de Cuenca, Ecuador.

Received: July 5, 2020.
Accepted: August 21, 2020.
Published: December 31, 2020.
Editor: Dr. Paúl Astudillo Neira

Bibliographic letterhead:

Rubio A, Escalante P. Predictive variables for endotracheal tube size in pediatric patients in the intensive care unit. Rev. Ecuat. Pediatría 2020; Article 19:1-7. doi: 10.52011/0032

DOI:
https://doi.org/10.52011/0032

Abstract

Introduction: A major cause of pediatric morbidity and mortality is airway compromise; thus, proper intubation is an important life-saving procedure. The objective of this study was to determine the predictive variables of diameter and length of the endotracheal tube in intubated children in the intensive care area of the Vicente Corral Moscoso Hospital, Cuenca, Ecuador.

Methods: In the present observational study with a non-probabilistic census-type sample, we measured the endotracheal tube diameter (ETD) and used X-ray to determine insertion depth and endotracheal tube length (ETL). We used correlation and linear regression analysis to predict ETD and ETL based on age, weight and height of children 1 to 120 months of age. Non-parametric statistics were used.

Results: There were 102 cases, constituting an intubation frequency of 30.6%, and the most frequent reason was respiratory disease. We establish statistically significant prediction equations for ETD (R2 = 0.65, P = 0.0001) and ETL (R2 = 0.65, P = 0.0001). ETD = 3.54 + 0.14 * (age years) + 0.04 * (weight kg). ETL = 10.36 + 0.31 * (age years) + 0.18 * (weight kg).

Conclusions: The diameter and length of the endotracheal tube are correlated with patient-specific variables, such as age and weight.

Keywords: Intubation, Intratracheal; Child; Intensive Care Units, Pediatric; Trachea.

*Corresponding author

Email: evelyn_2r@hotmail.com (Rubio Ramírez Adriana Evelyn) Servicio de Pediatría, Hospital Vicente Corral Moscoso. Av. 12 de Abril y Paraíso, Cuenca, Ecuador.

Introduction

Orotracheal intubation is a frequent procedure that can be challenging to execute due to the characteristics of the pediatric airway. It presents several complications, which can vary from 0.1% and considerably higher since multiple factors are implicit in its execution [1-3]. Respiratory problems that compromise ventilation are among the main causes of morbidity worldwide, regardless of the underlying condition; thus, adequate intubation can save lives [4, 5].

To perform the procedure, anatomical and physiological references of the airway must be considered, for which multiple methods have been published. These methods allow for selection based on tube size and insertion depth, although there are currently no fully reliable technical confirmations to verify tube position. Instead, it must be complemented and confirmed by clinical signs, pulse oximetry, capnography, chest X-ray, etc. [6].

Most of the literature related to intubation refers to adult and pediatric patients in developed countries using various methods and varied formulas. There are few studies related to intubation and its verification in the Latin American pediatric population, which is why which the present study was conducted. The objective of this study was to determine the predictive variables of diameter and length of endotracheal tube insertion in children aged 1 to 120 months admitted to the Intensive Care Unit of the Vicente Corral Moscoso Hospital.

Population and Methods

Study design

The present study is descriptive and correlational.

Stage

The present study was conducted in the Intensive Care Unit and emergency critical care area of the Vicente Corral Moscoso Hospital of the Ministry of Public Health of Cuenca, Azuay, Ecuador. The observational period was from May 1, 2018 to October 31, 2019. Data collection was completed on November 12, 2019.

Participants

Children with an age less than or equal to 10 years (120 months) who were admitted to the intensive care service and required intubation participated. Patients who did not have complete data for analysis were excluded.

Variables

The independent variables were sex, age, weight, and height. The dependent variables were tube diameter and length. Moderating or confounding variables included nutritional status, causes of intubation, proper tube placement, and complications.

Data sources

The data source was direct observations in the Intensive Care Unit by the author and collaborators. Data were collected using a form.

Procedures

Once the patient was intubated and in intensive care, the diameter of the tube used was measured. Using chest radiograph (post-intubation), the insertion depth of the tube was established in centimeters. Tube placement and radiography procedures constitute the usual treatment protocol in the Intensive Care Unit.

Control of sources of bias

A reassessment of the quality and fidelity of the data was conducted 24 hours after the placement of the endotracheal tube. When the tube was placed by the on-duty personnel, then the assessment was carried out with the cooperation of personnel and confirmed by the principal investigator once he entered the new shift.

Study size

The sampling was non-probabilistic; all possible cases of intubation during the period were included in this report.

Management of quantitative variables

The discrete variables are presented as frequency and percentages (%). 95% confidence intervals are used for proportions.

Statistical Methods

Once the data were collected using the form, they were entered into the IBM SPSS 15 statistical program (0 free version). A Kolmogorov-Smirnov test was performed to determine normality and based on this, we selected the appropriate use of parametric tests, such as medians.

To determine the prevalence of intubation in the unit, the total number of intubated patients during the study period was considered as the numerator and the total number of patients admitted to the unit during the same period as the denominator. The result was multiplied by one hundred to be expressed as a percentage.

In the bivariate analysis (hypothesis testing), the following tests were used depending on the crosses: qualitative (sex) with quantitative (tube diameter and length), the Mann-Whitney U; quantitative (age, weight and height) with quantitative (diameter and length of the tube), Spearman correlation.

Finally, a multivariate linear regression analysis was performed. First, the diameter of the tube was considered the dependent variable and then the length of the tube used. The independent variables (predictors) were sex (male and female), weight in kilograms, and height in meters. A final prediction equation of said intubation parameters was modeled and Pearson's coefficients were obtained for each equation. An adequate correlation was considered in percentages greater than 60%. Finally, ANOVA analysis was performed for regression and step-by-step analysis. The correlation between variables was considered statistically significant when the P value was <0.05. We verified whether each predictor variable was associated with the result in the coefficients table by considering the common association P value <0.05 to be significant. The data obtained are represented in tables.

Results

Participants

The number of patients was 103. The flow diagram is represented in Figure 1. Of the patients admitted to the ICU/Critical Emergency Area, 103/337 (30.56%) (95% CI 30.3-30.83%) required intubation.

Participant characteristics

There were 54/102 females, comprising the majority of cases, aged 1 to 24 months and with adequate nutritional status. The most prevalent etiology to cause intubation was pneumonia (see Table 1).

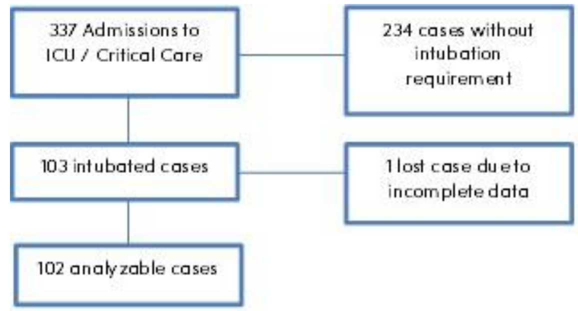

Fig. 1 Flowchart of study participants.

Table 1 General descriptions of the group.

Variables	Frequency	Percentage
	Age	
1 a 24 months	69	67.6%
25 a 48 months	11	10.7%
49 a 72 months	14	13.8%
73 a 96 months	6	5.9%
97 a 120 months	2	1.9%
	Sex	
Male	48	47.1%
Female	54	52.9%
	Nutritional condition	
Eutrophic	56	54.9%
Malnutrition	46	45.1%
	Diagnosis	
Severe pneumonía	23	22.5%
Heart disease	21	20.5%
Septic shock	11	10.8%
Severe head trauma	7	6.9%
Epileptic status	6	5.8%
Others	34	33.3%

Main results

In 95/102 cases, an adequate diameter of the endotracheal tube was used. As shown in Table 2, an adequate tube diameter was used in 93.1% of the cases and the placement depth was adequate in 65/102 cases. In 13/102 patients, complications were identified (12.75% 95% CI 12.10-13.39%), and the most frequent was air leak (46.2%) (see Table 2). There were no differences in the tube diameter in males versus females (4.0 and 4.3, respectively; P= 0.934). Nor were there differences in tube length in males 12, and females (12.0 and 12.3, respectively; P= 0.946).

Table 2 Diameter, depth, number of attempts and complications

Variable(s)		Frequency n=102	Percentage
Diameter	Inadequate	7	6.9
Depth	Inadequate	37	36.3
Attempts	> 3	18	17.6
	<= 3	84	82.4
Complications	Present	13	12.7
Type of complication	Air leak	6	46.2
	Displaced	1	7.7
	Atelectasis	3	23.1
	Selective (bronchial)	3	23.1

Table 3 Multiple linear regression between age-weight-height versus ETD

Model	Variable(s)	Standardized B coefficient	*t*	*P*
1 R^2=0.65	Constant		10.247	<0.0001
	Age (years)	0.437	2.597	0.011
	Weight (Kg)	0.328	1.670	0.098
	Size (M)	0.060	0.279	0.781
2 R^2=0.649	Constant		36.142	<0.0001
	Age (years)	0.459	3.129	0.002
	Weight (Kg)	0.364	2.480	0.015

ETD: endotracheal tube diameter

Table 4 Multiple linear regression between age-weight-height versus ETL

Modelo	Variable(s)	Standardized B coefficient	*t*	*P*
1 R^2=0.65	Constant		9.933	<0.0001
	Age (years)	0.324	1.929	0.057
	Weight (Kg)	0.494	2.523	0.013
	Size (M)	0.006	0.030	0.976
2 R^2=0.651	Constant		34.255	<0.0001
	Age (years)	0.326	2.228	0.028
	Weight (Kg)	0.498	3.403	0.001

ETL: endotracheal tube length

Association Analysis

There were statistically significant associations between height and ETD, weight and ETD, and age and ETD. There were also associations between ETL and these variables (Figure 2).

ETD prediction

When performing multiple linear regression to predict ETD based on the patient's age, weight, and height, only age and weight were predictive factors in a second model (Table 3). Thus, the ETD prediction equation = 3.54 + 0.14 * (age years) + 0.04 * (weight kg).

ETL prediction

When performing multiple linear regression to predict ETL based on the patient's age, weight, and height, only age and weight were predictive factors in a second model (Table 4). Thus, the ETL prediction equation = 10.36 + 0.31 * (age years) + 0.18 * (weight kg).

Discussion

The prevalence of intubation in the present study is relatively low (30.56%); it can vary from 10.4% to 44.8% [7-9]. Respiratory pathology was the main reason for intubation, which is consistent with the international literature [10, 11].

The adequate use of the tube diameter in the present investigation was high, which is similar to previous reports [10]. However, this is different from other locations, such as Souza Neilo in Sao Paulo [11], and Neunhoeffer in Germany [12], where the margin of error increases. These results could be explained by differences in the characteristics of the study population, the expertise of the healthcare professionals, or the formula/method that the operator chose to select the tube, all of which are conditions that can affect the success of the procedure.

Regarding the depth of insertion of the endotracheal tube, in the present investigation it was adequate in 63.7% of the patient, which is similar to reports from 2009, 2011 and 2016 that vary from 63 to 80% [9, 12, 13]. However, our percentage is different from a 2008 publication [14] in which adequate positioning was 82%.

Choosing the appropriate diameter and length of the endotracheal tube is important to avoid complications inherent to the procedure, such as air leak, tube displacement out of the airway, atelectasis, and selective intubation. In the present investigation, complications were low, but they can reach up to 46.5% [10], similar to that reported by Nakayama in Pennsylvania and Rodríguez in Colombia [15]. It should be noted that other complications such as bradycardia, oxygen saturation, arrhythmias, etc. may occur, but these were not taken into account in the present research.

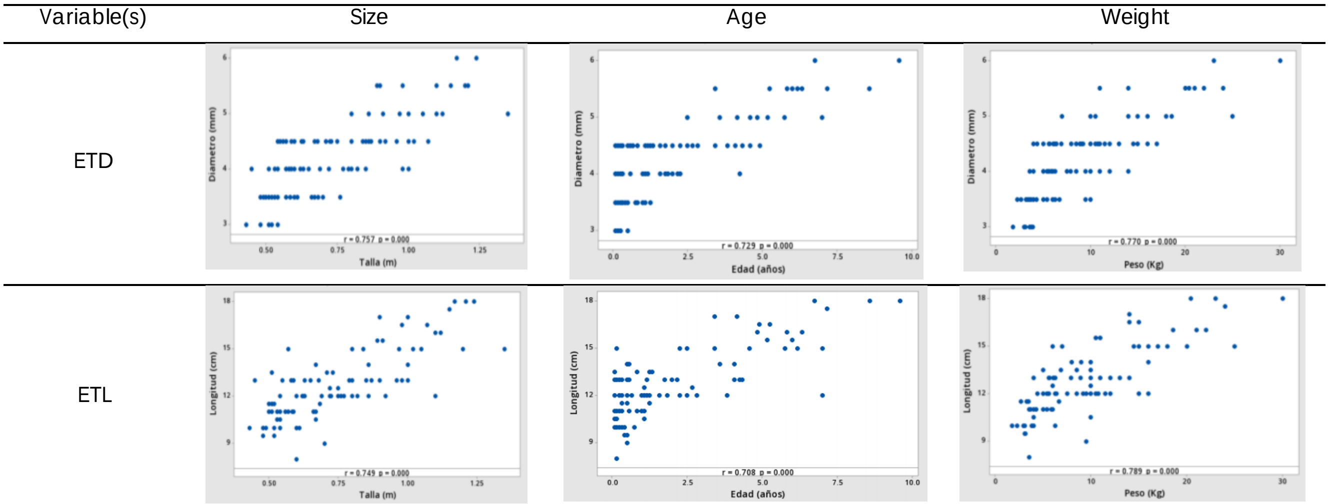

Fig. 2 Matrix of scattergrams between the endotracheal tube diameter (ETD) and length (ETL) with height, age and weight.

The age, height, and weight of the patients in the present study individually present a considerable predictive index of the diameter of the endotracheal tube. ETD can be estimated based on each of these variables, becoming more precise with age, as confirmed by Eck Jhon [16] in 2002 in a study involving the North American population, Naveen Eipe [17], Furuya [18] in China, Saowapark [19] in Thailand (children without heart disease) and Subramanian et al [20] in India where they specify that age has a higher prediction index in those older than 6 months. In the aforementioned studies, the predictions vary between 54 % to 62%. In contrast to those proposed by Neil [21] in 2015, which showed that age greatly underestimates the size of the tube, Hofer [22] in 2002 in Switzerland concluded that weight measured by Broselow tape is more accurate than age, and in Japan, Wang [23] in 1997 and Mingh [24] in 2008 defined height as a variable with greater predictive power when selecting tube diameter. Overall, it can be concluded that this large number of investigations add importance and validity to the result obtained in the present study and further demonstrate that there are no great differences between the European and American populations for the selection of endotracheal tube. Thus, this equation can be applied to our population.

In 2015, Boensh [25] reviewed a large variety of formulas published to date for estimating the depth of insertion of the endotracheal tube that considered height, age, and weight as predictive variables. In the present study, the length at which the endotracheal tube was located was not adequate in a high percentage. Weight and age show a correlation, which is greater based on weight, as confirmed by Lau Nicky [26] in 2006 in patients under one year of age. In contrast, Edmond [27] reported that height had a higher correlation with tube depth estimates. In 2016, the British Society of Anesthesiology [12], conducted a pilot study that validated body surface (height and weight) as a variable to estimate tube depth. Additionally, a 2005 study by Unpierre in Brazil [28] determined age was the most precise variable (62%). Taking into account these results, it can be concluded that there is no consensus to determine tube depth with greater accuracy. Thus, the formula proposed in the present study, when applied in clinical practice, does not estimate a real and safe value in infants. This may be due to multiple circumstances that were not taken into account in the current study, such as classification of the population by age group, malformations or underlying pathologies, head position during X-ray, formula or method that the operator used, etc. These are limitations of this study and are a reason further research should be conducted.

Conclusions

In this study, there was a low percentage of complications during the procedure; however, these are specifically limited to the procedure, and not to clinical complications. To estimate the tube diameter, age can be used with greater precision based on the equation presented in our study. Also, greater predictive power can be obtained by combining both age and weight in a single equation. Tube insertion depth was inadequate in a non-negligible percentage, which was significantly related to age and weight. Sex is not a variable that can be used to predict tube depth and diameter.

Abbreviations

ETD: endotracheal tube diameter. ETL: endotracheal tube length. ICU: intensive care unit.

Acknowledgments

We want to thank the intensive care unit staff of the "Vicente Corral Moscoso" Hospital in Cuenca - Ecuador, place where this work was performed.

Authors' contributions

AERR: Research idea, data collection, article writing, statistical analysis, editorial corrections.
PEC: Research idea, study design, critical analysis, research direction.
All authors read and approved the final version of the manuscript..

Authors information

Adriana Evelyn Rubio Ramírez, Physician from the Catholic University of Cuenca (2012), Specialist in Pediatrics from the University of Cuenca, Ecuador (2020). Email: evelyn_2r@hotmail.com https://orcid.org/0000-0002-3772-6257
Paúl Escalante Canto, Doctor in Medicine and Surgery, from the Catholic University of Cuenca (2003), Specialist in Pediatrics, from the University of Cuenca (2008).

Funding

The authors financed the expenses incurred in the production of this article.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due participant confidentiality but are available from the corresponding author on reasonable request.

Ethical statements

The protocol was approved by the Bioethics Committee of the Universidad de Cuenca and Teaching Department of the Vicente Corral Moscoso Hospital.

Protection of persons

The authors declare that the procedures followed were in accordance with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of the data

The authors declare that they have followed the protocols of their work center on the publication of patient data.

Consent for publication

The authors have obtained the informed consent from the caretakers of the patients referred to in the article. This document is in the possession of the corresponding author. The parents have signed the authorization for publication of this article.

Competing interests

The authors have no competing interests to declare.

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