RESEARCH PAPER

Normative Data of Optimally Placed Endotracheal Tube by Point-of-care Ultrasound in Neonates

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Objective: To derive normative data of the distance between optimally placed endotracheal tube tip and arch of aorta by ultrasound in neonates across different weight and gestation.

Design: Cross-sectional study.

Setting: Tertiary care neonatal intensive care unit from April 2015 to May 2016.

Participants: All neonates requiring endotracheal intubation were eligible for the study.

Methods: During intubation, insertional length was determined using weight-based formula. The distance between endotracheal tube tip and arch of aorta was measured by ultrasound. Endotracheal tube position was confirmed by chest radiograph.

Results: Out of 133 enrolled infants, 101 (75.9%) had optimally placed endotracheal tubes. The mean (SD) distance between endotracheal tube tip and arch of aorta by ultrasound was 0.78 (0.21) cm in infants <1500 g and 1.04 (0.32) cm in infants ≥1500 g. The regression equation to estimate insertional length from weight, crown heel length (CHL), occipito-frontal circumference (OFC), nasal tragus length (NTL) and sternal length (SL) were Wt(kg)+4.95, 0.15×CHL(cm)+0.57, 0.22×OFC(cm)+0.49, 0.82×NTL(cm)+1.24 and 0.75×SL(cm)+2.26, respectively.

Conclusion: Our study reports normative data of the distance between optimally placed endotracheal tube tip and arch of aorta by ultrasound in neonates. The distance between endotracheal tube tip and arch of aorta increases with increase in weight and gestation. Insertional length correlates strongly with all the anthropometric parameters.

Keywords: *Arch of aorta, Intubation, Insertional length.*

Clinical Trial Registration: CTRI/2017/05/008718.

Endotracheal intubation is a commonly performed procedure in neonates. Optimum placement of endotracheal tube (ET) in the trachea requires high degree of precision. Malplacement of ET results in complications including pneumothorax, lung collapse, tracheal damage and unplanned extubation [1]. Placement of ET up to optimum depth (insertional length, IL) has been predicted based on various anthropometric parameters such as weight, gestation, sternal length (SL), nasal tragus length (NTL), occipital frontal circumference (OFC), crown heel length (CHL) and foot length [2-4]. However, despite using clinical predictors of IL, malposition of ET has been reported to be as high as 58% [5]. The gold standard to confirm ET position is chest radiograph. However, radiograph carries disadvantage of radiation exposure, excessive handling of sick infants and time delay [6]. In addition, it may not be feasible to use *X*-ray when duration of intubation is brief *e.g.*, during surfactant administration.

Point of care ultrasound (USG) has been found to be a safe and feasible modality to determine ET tip position in neonates [7-11]. An ET tip placed 0.5-1 cm above the arch of aorta suggests its correct placement [7,11]; though, it has been defined irrespective of weight and gestation [16,20]. On the contrary, the length of the trachea has been reported to be variable with weight, length and gestation [12-14]. Therefore, the present study was planned to derive normative data of the distance between optimally placed ET tip and arch of aorta across different birthweights and gestations by USG.

Methods

The study was conducted in the neonatal intensive care unit (NICU) of a tertiary-care centre in northern India from April 2015 to May 2016. All neonates admitted in NICU were screened for eligibility. Infants with known tracheal, esophageal, cardiac and cranio-facial anomalies and those with generalized edema were excluded. Informed consent was obtained from either parent of the infants, who were presumed to be at risk of intubation by the treating neonatologist. Following intubation, infants were re-assessed by the principal or co-investigator/s based on detailed clinical examination, chest *X*-ray or echocardiographic findings. Subjects found to be unsuitable for any of the anthropometric examination or ultrasound measurement including even minor abnormalities such as low set ear or depressed nasal bridge were further excluded. Each eligible infant was enrolled only once during the study period. The study was approved by the Institutional ethics committee and registered with Clinical trial registry of India (CTRI). The primary objective of the study was to measure the distance between optimally-placed ET tip and arch of aorta by USG across different weights and gestations. Secondary objective was to find out correlation between IL of optimally placed ET and various anthropometric parameters: weight, OFC, CHL, NTL and SL.

All intubations were done through oral route as per decision of the treating neonatologist. IL was decided by Tochen's formula (weight in (kg) + 6cm) [15]. Birthweight or current weight, whichever was higher, was used to estimate IL. After intubation, ET was readjusted by auscultation and fixed at a position where air entry was bilaterally equal. Neck position was maintained in slight extension with the help of a shoulder roll during USG and radiograph. After intubation and fixation of the ET, exact IL was calculated. The part of ET present exterior to the lips (A) was measured from a visible centimeter mark on the adapter end of ET to the corner of the lip with a paper tape following curvature of the ET. Exact IL was calculated by subtracting this length (A) from length of ET (B) up to that mark (***Web. Fig 1***). *X*-ray was ordered and USG was done to determine ET tip position following intubation. No change in ET position was done based on USG findings until *X*-ray film was available.

ET tip position was determined by USG following intubation using Sonosite M-Turbo portable ultrasound machine with phase array probe of 8-4 MHz frequency. To minimize the variability of USG measurements, only two of the investigators conducted all USG after appropriate training.

Mid-sagittal views were obtained by placing the probe on the infant's lower neck and upper sternum in order to visualize the ET. Warm gel was applied to the probe during USG. Care was taken to ensure adequate oxygenation and temperature regulation throughout the procedure. The bedside nurse was available to assist in calming the infant. Arch of aorta was visualized by gray scale and color Doppler. ET was identified as a linear echo dense structure. The ET tip was reliably delineated by producing a minimal gentle movement with the help of an assistant. Each image was zoomed and the distance of the ET tip from superior border of arch of aorta was measured in the line of ET (***Fig. 1***). A total of three observations were made for each subject and average of these measurements was taken. Both static images and video clips were recorded and stored in the flashcard of USG machine to be later transferred to the computer for storage. Twenty percent of the videos were analyzed by a pediatric cardiologist for validation. Time elapsed between end of intubation and completion of last measurement by USG was recorded.

In 25 intubated infants, USG was done in succession by both the investigators blinded to each other's findings. A total of three observations were made by each investigator for these infants. Intraclass correlation coefficient (ICC) and Bland-Altman analysis were used for measuring and testing the consistency, reliability and agreement of USG measurements between the two investigators. A strong intraclass correlation (ICC>0.9) was also observed between average USG readings of both the investigators (ICC 0.98; 95% CI 0.96 to 0.99). A strong intraclass correlation was also observed for all the three measurements of the investigators (ICC 0.93; 95% CI 0.91, 0.95; and 0.97; 95% CI 0.95, 0.99). Bland-Altman analysis (***Web Fig. 2***) showed mean difference of -0.02 mm (95% CI -0.05 to -0.01) in the measurements of the two co-investigators.

Corrective measure to place the ET in optimum position was taken by the treating neonatologist after availability of *X*-ray film. Time elapsed between intubation and availability of *X*-ray film was noted. All *X*-ray films were later reviewed by a radiologist and ET was classified as optimum (ET tip located between upper

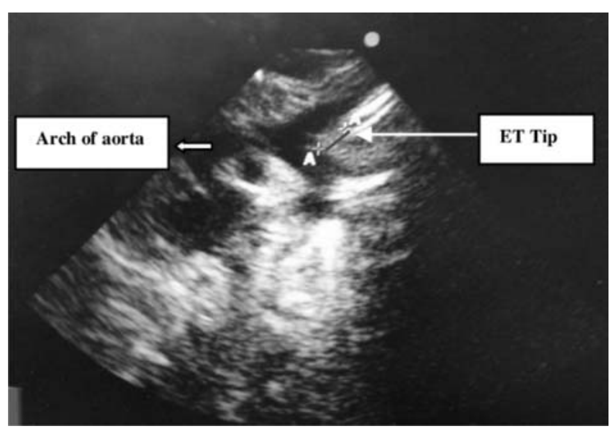


FIG. 1 *Demonstrates linear echo bright structure confirmed to be endotracheal tube (ET) by gently moving the tube; AA distance of ET tip from arch of aorta measured in the line of ET.*

border of T1 and lower border of T2 vertebral body), low (ET tip lying below lower border of T2 vertebral body) or high (ET tip situated above upper border of T1 vertebral body) [16].

All anthropometric measurements were made by a single investigator on the day of enrolment. OFC was recorded with a paper tape placed posteriorly on external occipital protuberance and anteriorly above supraorbital ridges. CHL was measured with the help of a length board (Seca 210) with knee extended and foot perpendicular to the ground. SL was measured from the suprasternal notch to the tip of the xiphoid process. NTL was noted from the base of the nasal septum to the tip of the tragus. A total of three readings were made for each parameter and mean of these readings was calculated.

The primary outcome was to calculate the distance between optimally placed ET tip and arch of aorta across different weight and gestation by USG. Secondary outcome included correlation between IL of optimally placed ET and anthropometric parameters such as weight, OFC, CHL, NTL and SL.

A pilot study was conducted in 15 infants to calculate the mean and standard deviation (SD) of the distance between optimally placed ET tip from arch of aorta by USG. Among very low birth weight infants (birth weight <1500 g), mean (SD) was found to be 0.30 cm (0.11). Considering precision of 10% across the mean, sample size for very low birth infants was found to be 52. Similarly, for infants weighing >1500 g, mean (SD) was 0.60 cm (0.20) and considering a precision of 10%, sample size was found to be 42. Therefore, a total of 94 infants with optimally placed ET were required to derive normative data of the distance between optimally placed ET tip and arch of aorta by USG.

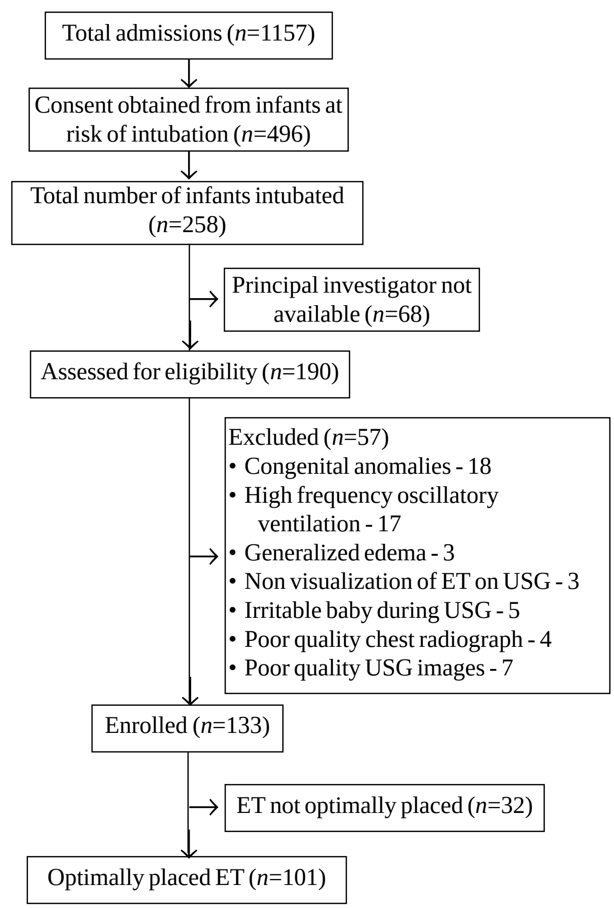
Statistical analysis: Analysis of data was done using SPSS software version 20.0. Chi square or Fisher's exact test was used to compare categorical variables. Student's *t* test and Mann Whitney test were applied to compare independent parametric and non-parametric variables, respectively. Non-parametric related samples were tested by Wilcoxon signed rank test. Two sided *P* value <0.05 was considered significant. Pearson's correlation and linear regression were used to analyze the relationship between anthropometric data (weight, OFC, CHL, NTL and SL) and IL. IL of correctly placed ET was the dependent variable and anthropometric parameters were independent variables for the correlation and regression analysis.

The intraclass correlation coefficient (ICC) was used to determine the consistency, reliability and reproducibility (inter and intra observer variability between two observers) of USG measurements across the two examiners. The corresponding limits of agreements were calculated by means of Bland-Altman analysis after assuring the normality of the differences between two sets of results (*i.e.*, the paired observations of principal investigator and co-investigator), which was examined using Kolmogorov–Smirnov test.

RESULTS

A total of 1157 infants were admitted during the study period. Consent was obtained for 496 infants at risk of intubation, out of which 258 were intubated. During 68 intubations, investigators were not available and an additional 57 infants were excluded due to various other reasons (***Fig.* 2**). A total of 133 infants were included, of which 101 had optimally placed ET on *X*-ray.

The baseline characteristic of enrolled infants is described in ***Table* I.** Mean (SD) IL and USG distance between optimally placed ET tip and arch of aorta in different weight and gestation groups is depicted in



ET: Endotracheal tube; USG:Ultrasonography.

FIG. 2 *Study flow chart.*

TABLE I BASELINE CHARACTERISTICS OF OVERALL STUDY POPULATION (*N*=133)

Parameter	*n (%)*
Gestation in (wk)*	30.8 (4.6)
Birth weight in (g)*	
<1500	992.7 (272.0)
≥1500	2480.1 (597.3)
PMA (wk)*	32.0 (5.3)
Weight at enrolment (g)*	
<1500	1028.9 (274.0)
≥1500	2456.1 (597.3)
Weight for gestation	
AGA	100 (75.2)
SGA	26 (19.5)
LGA	7 (5.3)
Gender	
Male	99 (74.4)
Weight enrolment groups (g)	
<1000	45 (33.8)
1000-1499	38 (28.6)
1500-1999	16 (12.0)
2000-2499	8 (6.0)
≥2500	26 (19.5)
PMA enrollment groups (wk)	
<28	31 (23.3)
28-31	37 (27.8)
32-35	25 (18.8)
≥36	40 (30.1)

*Data expressed as n (%) or *mean (SD); PMA: Post menstrual age; AGA: Appropriate for gestational age; SGA: Small for gestational age; LGA: Large for gestational age.*

***Table* II**. A total of 32 infants had malpositioned ET. Deep intubation was twice as common as high intubation (15.10% (21/133) *vs* 8.30% (11/133); *P*=0.02). Proportion of malpositioned ET in infants <1500 g was higher compared to infants ≥1500g (31.40% (26/83) *vs* 12% (6/50); *P*=0.01). Similarly, malposition was more common in infants of gestation <32 weeks compared to ≥32 weeks (33.80% (23/68) *vs* 13.90% (9/65); *P*<0.01). The median (IQR) time from intubation to completion of three readings of USG was less than the time required for obtaining *X*-ray film (12.00 (8.00-15.00) min *vs* 98.00 (64.00-132.00) min; *P*<0.001).

USG distance between ET tip and arch of aorta was also compared in infants <1500g *vs* ≥1500g and <32 weeks *vs* ≥32 weeks. Mean (SD) USG distance in VLBW population was significantly less than the mean distance for infants with weight >1500g (0.78 (0.21) *vs* 1.04 (0.32); *P*<0.001). Similarly, mean (SD) distance in infants with post menstrual age <32 wk was significantly less as compared to the distance for the population ≥32 weeks (0.77 (0.18) *vs* 1.01 (0.30); *P*<0.001). ***Table* III** illustrates centiles of the ultrasound distance between ET tip and arch of aorta across different weight and gestation groups. The degree of correlation between IL and anthropometric parameters and the regression equation to predict insertional length from weight, OFC, CHL, NTL and SL have been described in ***Table* IV.** Linear relationship between IL and various anthropometric parameters has been displayed in the figure (***Web Fig. 3a-3e)***.

TABLE II INSERTIONAL LENGTH AND NORMATIVE DATA OF THE DISTANCE BETWEEN OPTIMALLY PLACED ET TIP AND ARCH OF AORTA BY USG ACROSS DIFFERENT WEIGHT AND GESTATION CATEGORIES (*N*=101)

Categories	*Insertional length (cm) Mean (SD)*	*USG distance Mean (SD)*	*USG distance 95% CI*
Weight (g)			
<1000 (*n*=30)	5.80 (0.42)	0.73 (0.21)	0.65-0.80
1000-1499 (*n*=27)	6.46 (0.46)	0.86 (0.18)	0.79-0.94
1500-1999 (*n*=14)	6.97 (0.54)	0.94 (0.29)	0.77-1.12
2000-2499 (*n*=6)	7.26 (0.44)	0.98 (0.13)	0.84-1.13
≥2500 (*n*=24)	8.30 (0.54)	1.10 (0.35)	0.95-1.26
PMA Gestation (wk)			
<28 (*n*=20)	5.83 (0.41)	0.65(0.19)	0.58-0.76
28-31 (*n*=25)	6.20 (0.56)	0.83 (0.15)	0.77-0.90
32-35 (*n*=20)	6.84 (0.58)	0.94 (0.22)	0.84-1.04
≥36 (*n*=36)	7.78 (0.91)	1.04 (0.34)	0.93-1.16

ET: Endotracheal tube; PMA: Post menstrual age.

DISCUSSION

Endotracheal tube position can be confirmed by bedside USG without exposing the infant to radiation and handling [7,8,11,17]. Ultrasound studies have revealed that a distance of 0.5 to 1 cm between ET tip and arch of aorta suggests its correct placement [7,11]. However, this distance is likely to differ across different weight and gestation due to variation in tracheal length [12-14]. We conducted an observational study with the primary objective to derive normative data of the distance between optimally placed ET tip from arch of aorta by USG across different weight and gestation.

In our study, we determined the ET position by USG in mid-sagittal view and measured the distance between

TABLE III DISTANCE BETWEEN ENDOTRACHEAL TUBE TIP AND ARCH OF AORTA BY ULTRASONOGRAPHY ACROSS DIFFERENT GESTATION AND WEIGHT (*N*=101)

		Percentiles						
Parameter	*N*	*5th*	*10th*	*25th*	*50th*	*75th*	*90th*	*95th*
Weight (g)								
<1000	30	0.30	0.42	0.60	0.72	0.88	1.04	1.08
1000-1499	27	0.49	0.62	0.75	0.92	0.96	1.08	1.22
1500-1999	14	0.47	0.55	0.75	0.92	1.09	1.49	-
2000-2499	6	0.76	0.76	0.89	0.98	1.12	-	-
≥ 2500	24	0.50	0.58	0.76	1.12	1.39	1.61	1.75
Post-menstrual age (wk)								
<28	20	0.27	0.34	0.55	0.69	0.81	0.93	1.04
28-31 6/7	25	0.58	0.63	0.71	0.82	0.93	1.08	1.08
32-35 6/7	20	0.47	0.72	0.78	0.97	1.04	1.30	1.39
≥ 36	36	0.49	0.55	0.76	1.06	1.23	1.58	1.67

TABLE IV PEARSON'S CORRELATION (*r*) AND LINEAR REGRESSION EQUATIONS FOR INSERTIONAL LENGTH AND VARIOUS ANTHROPOMETRIC MEASUREMENTS (*N*=101)

Parameter	*r*	*P value*	*Regression equation (R^2)*
Weight (Kg)	0.906	<0.001	Wt (Kg) + 4.95
OFC (cm)	0.903	<0.001	0.223×OFC (cm)+0.49
NTL (cm)	0.898	<0.001	0.822×NTL (cm)+1.24
CHL (cm)	0.896	<0.001	0.154×CHL (cm)+0.57
STL (cm)	0.860	<0.001	0.752×STL (cm)+2.26

CHL: Crown heel length, OFC: Occipito frontal circumference, NTL: Nasal tragus length, STL: Sternal length, IL: Insertional length.

ET tip to arch of aorta in the line of ET. Our method was similar to that described by Slovis, *et al.* [7]. They observed that the distance of ET tip to carina on *X* ray and ET tip to arch of aorta by USG had good degree of correlation. Sethi, *et al.* [11], using a similar method, found that the distance between ET tip to arch of aorta was 0.5–1 cm in 48 out of 53 correctly placed ET. However, both the authors did not account for intra or inter-observer variability during USG measurements.

Lingle [8] described a modified technique to visualize the ET by using an USG 'stand-off pad' in 6 neonates, which obviated the need to extend the neck and therefore reduce the risk of tube displacement. This method was used only in six infants and lacks validation. In two other studies, Dennington, *et al.* [10] and Najib, *et al.* [18] measured the distance between ET tip to an anatomic equivalent of carina (superior portion of the right pulmonary artery) and found good correlation with radiograph [10,18]. Chowdhry, *et al.* [17] measured the distance from the point of maximal curvature of the arch of aorta to the ET tip by USG and a minimum distance of 1 cm was used to define "not deeply placed ET". This distance was derived from preliminary analysis of computed tomography scans of infants between zero to three months of age. The study reported a concordance of 94.6% between USG and radiograph [17]. However, in none of these studies, authors reported variation in measurements across different weight and gestation.

In our study, we found that the distance between optimally placed ET tip from arch of aorta increases with increase in weight and gestation. Anatomical studies can explain our results. In a prospective study of routine autopsies which included 274 fetuses (15-41 weeks) and 26 infants (0 to 3 months), anatomical measurements of larynx and trachea showed linear relationship between tracheal length and gestational age, body weight and length [13]. In term infants, trachea measures 5-6 cm, whereas in premature infants it can be as short as 3 cm [19, 20]. Therefore, a distance of 0.5-1 cm between ET tip and arch of aorta as suggested by previous authors may not result in optimum placement of ET in all the infants. Our study is in agreement with the biological plausibility of variation in tracheal length and reports variation in the USG distance of ET tip from arch of aorta in infants of various weight and gestation.

We also compared the time required for obtaining *X*-ray film and USG. The mean (SD) time taken to conduct USG from the time of intubation was less than the time required for availability of *X* ray film. Lesser mean (SD) time taken to conduct USG as compared to radiograph

WHAT IS ALREADY KNOWN?

- Ultrasound is a feasible tool to determine endotracheal tube position and has good agreement with chest radiograph.

WHAT THIS STUDY ADDS?

- This study provides normative data using ultrasound for the distance between endotracheal tube tip and arch of aorta across various weight and gestation groups.

has previously been also reported [11]. The time required for radiograph may vary depending on the setup, availability of bedside machine and technician, and time required to develop and deliver the *X*-ray film to the clinician. On the contrary, point of care USG and availability of personnel at the bedside avoids unnecessary delay in confirmation of ET tip position.

In clinical practice, IL is predicted based on various anthropometric parameters [2-4]. In our study, IL correlated strongly with anthropometric parameters (weight, CHL, OFC, NTL and SL). NRP guidelines till 2010 recommended weight-based formula given by Tochen (Wt in kg + 6 cm) for deciding IL [21-23]. However, we found that the regression equation that best predicted IL for optimum placement of ET is wt in kg + 4.95 cm. Our findings suggest that in our population Tochen's formula overestimates IL by approximately 1 cm. In another study from India, Tatwavedi, *et al.* [16] also showed similar relationship between weight and IL [IL=weight in kg +5 (r=0.81, P<0.001)]. Similarity in Tatwavedi and our findings may be due to similar population enrolled and the variation from other studies may be attributed to racial difference in tracheal size [24-26].

Weight may not be available immediately after birth or during emergencies and may be fallacious in infants who are edematous or dehydrated. One of the easily measurable anthropometric parameter for prediction of IL is NTL. It can be measured quickly as the two landmarks, base of the nasal septum and tragus are well defined and fixed. In addition, NTL measurement can be done without disturbing the sick infant. As per the regression equation in our study, IL can be predicted as 0.82 NTL (cm) +1.24. NRP 2015 guidelines also endorse use of NTL to decide IL [27]. In our study, we found good correlation between IL and other anthropometric parameters (SL, OFC and CHL). However, their regression equations seem complicated, difficult to memorize and use in clinical practice. We also observed that it was difficult to measure SL in infants with marked chest retractions.

The mean and SD of the distance between ET tip and arch of aorta calculated in the pilot study are different from the final results. Considering the final results, sample size would have been smaller; however due to paucity of literature, we were dependent on the pilot study to calculate the required sample size. The limitation of our study is that it only reports the normative data but it does not validate what proportion of ET would be optimally placed by using this data.

Our study reports the normative data of the distance between optimally placed ET tip and arch of aorta by USG in neonates. However, we emphasize that USG is a skill-based technique and competency training is required before this normative data can be used in clinical practice. In addition, we conclude that IL can be predicted based on various anthropometric parameters such as weight, CHL, OFC, NTL and SL.

Contributors: AT: conceptualized and designed the study, provided training to perform ultrasound, supervised data collection, conducted statistical analysis and helped in manuscript writing; PS, AT: performed ultrasounds, collected data and drafted initial manuscript; NK, PG: study design, supervised the conduct of the study and helped in manuscript writing; NA: was involved in planning the study and analyzed and validated the videos of ultrasound. All authors approved the final manuscript.
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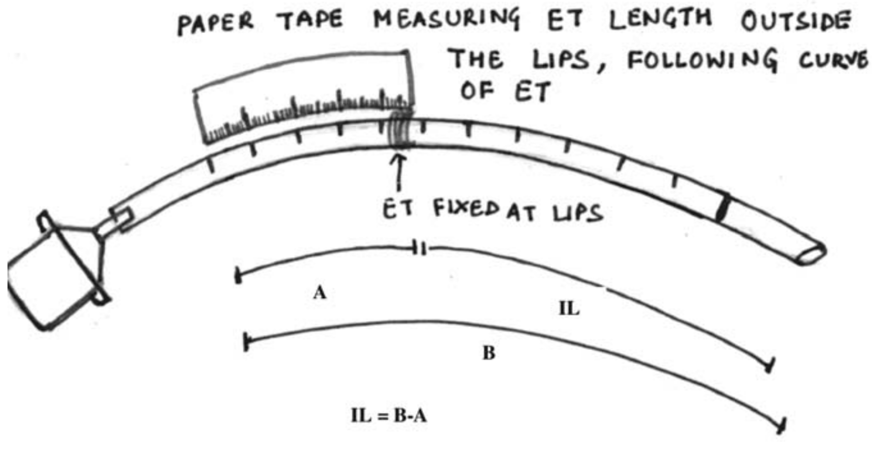
REFERENCES

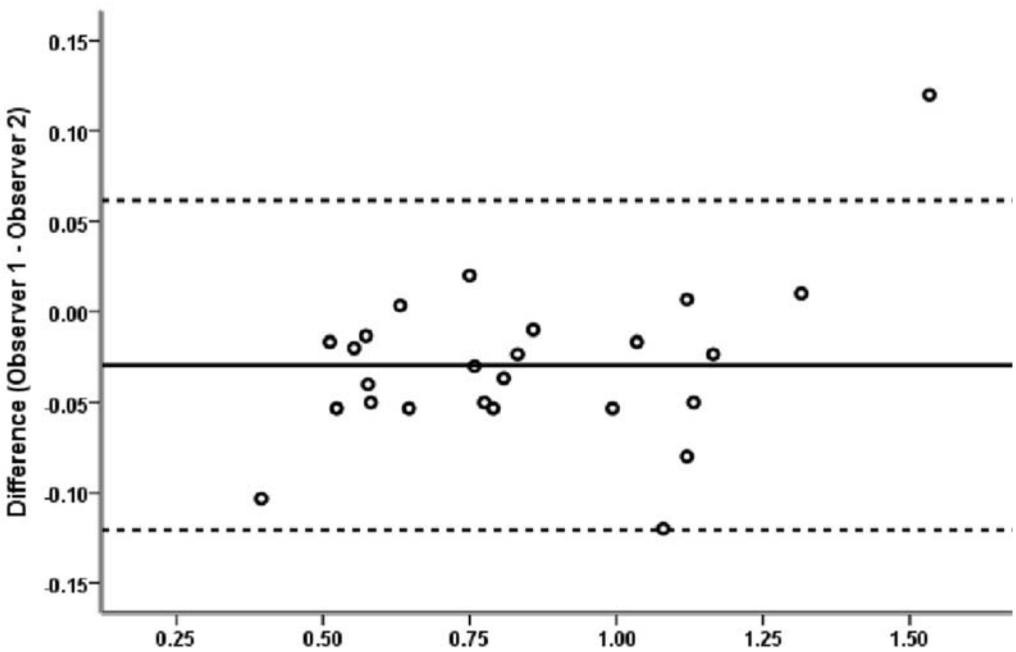
1. da Silva O, Stevens D. Complications of airway management in very-low-birth-weight infants. Biol Neonate. 1999;75:40-5.
2. Shukla HK, Hendricks-Munoz KD, Atakent Y, Rapaport S. Rapid estimation of insertional length of endotracheal intubation in newborn infants. J Pediatr. 1997;131:561-4.
3. Kempley ST, Moreiras JW, Petrone FL. Endotracheal tube length for neonatal intubation. Resuscitation. 2008;77:369-73.
4. Embleton ND, Deshpande SA, Scott D, Wright C, Milligan DW. Foot length, an accurate predictor of nasotracheal tube length in neonates. Arch Dis Child Fetal Neonatal Ed. 2001;85:F60-4.
5. Mainie P, Carmichael A, McCullough S, Kempley ST. Endotracheal tube position in infants requiring emergency interhospital transfer. Am J Perinatol. 2006;23:121-4.
6. Poznanski AK, Kanellitsas C, Roloff DW, Borer RC. Radiation exposure to personnel in a neonatal nursery.

Pediatrics. 1974;54:139-41.

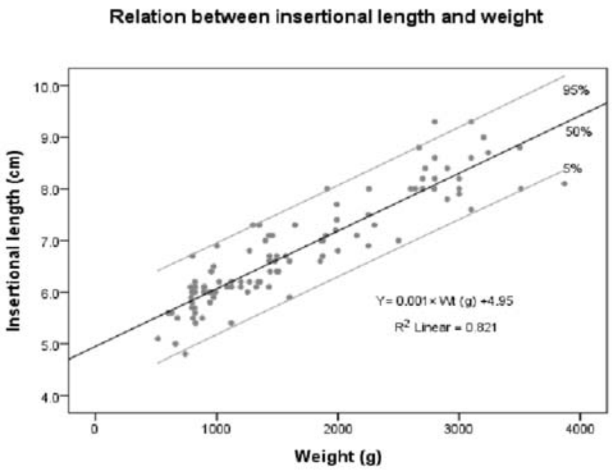
7. Slovis TL, Poland RL. Endotracheal tubes in neonates: Sonographic positioning. Radiology. 1986;160:262-3.
8. Lingle PA. Sonographic verification of endotracheal tube position in neonates: A modified technique. J Clin Ultrasound. 1988;16:605-9.
9. Galicinao J, Bush AJ, Godambe SA. Use of bedside ultrasonography for endotracheal tube placement in pediatric patients: A feasibility study. Pediatrics. 2007;120:1297-303.
10. Dennington D, Vali P, Finer NN, Kim JH. Ultrasound confirmation of endotracheal tube position in neonates. Neonatology. 2012;102:185-9.
11. Sethi A, Nimbalkar A, Patel D, Kungwani A, Nimbalkar S. Point of care ultrasonography for position of tip of endotracheal tube in neonates. Indian Pediatr. 2014;51:119-21.
12. Wailoo MP, Emery JL. Normal growth and development of the trachea. Thorax. 1982;37:584-7.
13. Fayoux P, Marciniak B, Devisme L, Storme L. Prenatal and early postnatal morphogenesis and growth of human laryngotracheal structures. J Anat. 2008;213:86-92.
14. Szpinda M, Daroszewski M, WoŸniak A, Szpinda A, Mila-Kierzenkowska C. Tracheal dimensions in human fetuses: an anatomical, digital and statistical study. Surg Radiol Anat. 2012;34:317-23.
15. Tochen ML. Orotracheal intubation in the newborn infant: a method for determining depth of tube insertion. J Pediatr. 1979;95:1050-1.
16. Tatwavedi D, Nesargi SV, Shankar N, Rao S, Bhat SR. Evaluation of body parameters for estimation of endotracheal tube length in Indian infants. Eur J Pediatr. 2015;174:245-9.
17. Chowdhry R, Dangman B, Pinheiro JM. The concordance of ultrasound technique versus *X*-ray to confirm endotracheal tube position in infants. J Perinatol. 2015;35:481-4.
18. Najib K, Pishvs N, Amoozegar H, Pishdad P, Fallahzadeh E. Ultrasonographic confirmation of endotracheal tube position in neonates. Indian Pediatr. 2016;53:886-8.
19. Griscom NT, Wohl ME. Dimensions of the growing trachea related to age and gender. AJR Am J Roentgenol. 1986;146:233-7.
20. Standring, S, editor. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st ed. New York: Elsevier Limited; 2016.
21. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 11: Neonatal Resuscitation. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Circulation. 2000;102:I343-57.
22. American Heart Association. 2005 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular care (ECC) of Pediatric and Neonatal Patients: Pediatric basic life support. Pediatrics.2006;117:e989-1004.
23. Kattwinkel J, Perlman JM, Aziz K, Colby C, Fairchild K, Gallagher J, *et al*. Part 15: Neonatal Resuscitation: American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122:909-19.
24. Allen MS. Surgical anatomy of the trachea. Chest Surg Clin N Am. 2003;13:191-9.
25. Mi W, Zhang C, Wang H, Cao J, Li C, Yang L, *et al*. Measurement and analysis of the tracheobronchial tree in Chinese population using computed tomography. PLoS One. 2015;10:e0123177.
26. Cinar U, Halezeroglu S, Okur E, Inanici MA, Kayaoglu S. Tracheal length in adult human: The results of 100 autopsies. Int J Morphol. 2016;34:232-6.
27. Wyckoff MH, Aziz K, Escobedo MB, Kapadia VS, Kattwinkel J, *et al*. Part 13: Neonatal Resuscitation: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132:S543-60.



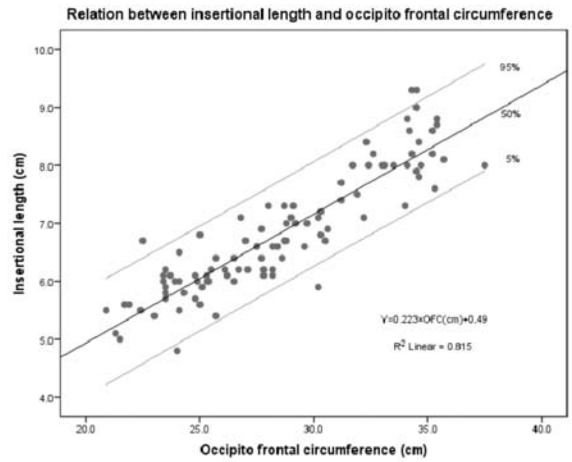
WEB FIG. 1 *Measurement and calculation of insertional length (IL).*



WEB FIG. 2 *Bland-Altman plot of average distance measured by ultrasound by observer 1 versus observer 2.*



(a)



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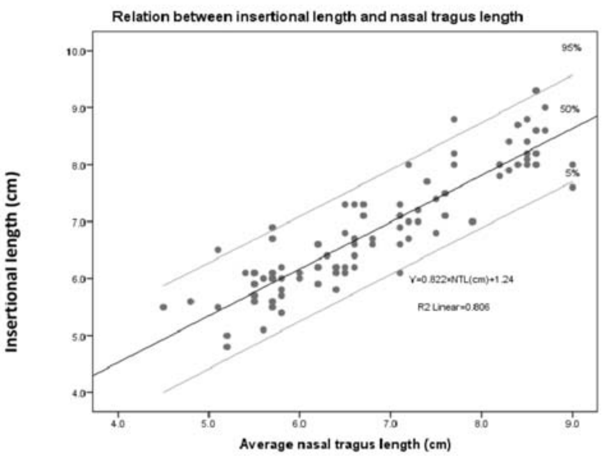
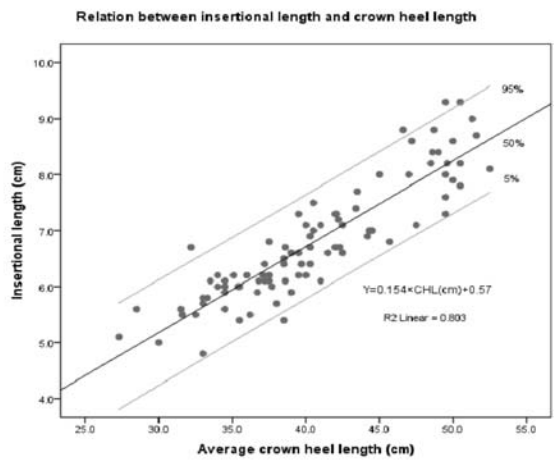


(c)



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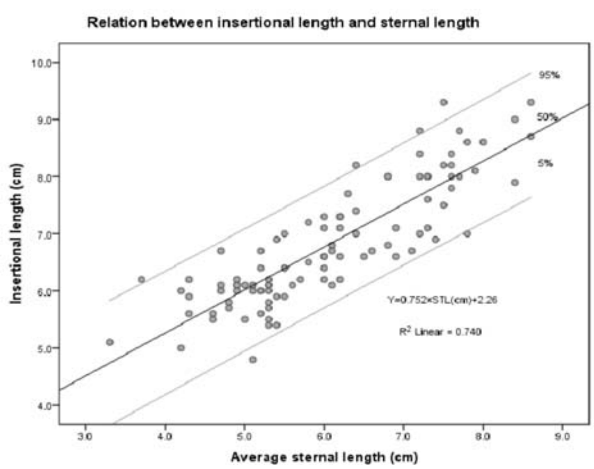

(e)

WEB FIG. 3 *(a) Linear relationship between insertional length and weight at enrolment, (b) Linear relationship between insertional length and occipital frontal circumference, (c) Linear relationship between insertional length and nasal tragus length, (d) Linear relationship between insertional length and crown heel length, and (e) Linear relationship between insertional length and sternal length.*