Bedside prediction of airway length by measuring upper incisor manubrio-sternal joint length

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Abstract

Background: Malpositioning of endotracheal tube may lead to serious complications like endobronchial intubation or accidental extubation. Using anatomical measurements for prediction of airway length would be more practical in resource constrained settings.
Materials and Methods: One hundred adult patients of American Society of Anesthesiologists (ASA) grade 1 or 2, without any evidence of difficult airway, were randomly allocated to two cohorts — a model cohort of 70 (50 males) and test cohort of 30 (20 males) subjects. Height, the straight length from the upper incisor to manubrio-sternal joint in fully extended head position (IncManustL), the length from upper incisor to the carina in neutral head position (IncCarinaL), and degree of neck extension were measured in all subjects. Relationship between the two lengths in the model cohort was explored by Pearson's coefficient (r). Predictions were made for subjects in the test cohort and actual and predicted values assessed for agreement using intra-class correlation coefficient (ICC).
Results: Good agreement was found between IncManustL and IncCarinaL for both male (r = 0.69) and female (r = 0.54) subjects. Multiple regression analysis suggested height to be another significant predictor, unlike age, weight, and neck extension. The gender-specific regression equations were used to predict IncCarinaL for the test cohort. ICC for absolute agreement between the actual and predicted values was 0.723 (95% CI 0.495-0.858).
Conclusions: It is possible to predict airway length in adult Indian subjects by making two simple anatomical measurements, namely stature and incisor manubrio-sternal joint length.

Key words: Airway length prediction, incisor carina length, upper incisor manubrio-sternal joint length

Introduction

Malposition of endotracheal tube within the airway can lead to serious complications.[1,2] Over-insertion may produce endobronchial intubation,[3] one lung ventilation, and collapse of the other lung that may finally lead to hypoxia. Bronchial intubation accounts for 4% of the adverse respiratory events in pediatric patients and 2% in adults with higher incidence in females.[4] On the other hand, under-insertion of the tube may wrongly place the inflated cuff over the vocal cords leading to vocal cords trauma and even accidental extubation.[5] Therefore, prediction of correct depth of endotracheal tube is important and should be individualized. Various landmarks, formulae, and methods[6-8] have been proposed for proper positioning of the tube at an adequate depth, but results are not always encouraging.[9,10]

The tip of the endotracheal tube should be positioned at the midpoint of the trachea. Clinical examination is not very sensitive in this regard. Chest X-ray has been used to confirm proper positioning of the endotracheal tube,[11] but it is costly and time consuming. Therefore, even though it is accepted as an effective technique in the intensive care setup, it has not gained much acceptance in operation theaters. Fiberoptic bronchoscopy is the most definitive way of confirming placement of the endotracheal tube tip[12] as it provides real time visualization; however it requires expertise to handle, is costly, and not available routinely in operation theaters.

Height of a person[13] and different anatomical landmarks[14] have been used frequently for prediction of airway length with

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variable success. Angle of Louis, the forward prominence formed by the manubrio-sternal joint, is at the same horizontal plane as the tracheal carina and is an important anatomical landmark. Rigid bronchoscope being a straight and nonmalleable structure; during its insertion, patient's pharynx, larynx, and trachea have to be placed in one line and his neck would have been placed in extended position. Therefore, the straight length from the upper incisor to the manubrio-sternal joint in fully extended head position can be expected to be similar to the real airway length from upper incisor to the carina. Lee *et al.*,[15] had compared the straight length from the upper incisor to manubriosternal joint in extended head position with the upper incisor carinal length in neutral head neck position and found a strong correlation between the two.

Data for Indian population regarding use of anatomical landmarks and dimensions in predicting airway length for safe placement of the endotracheal tube is not available. Therefore, the present study was planned to find out the relationship between upper incisor manubriosternal joint length in extended head position (IncManustL) and upper incisor carina length in neutral head position (IncCarinaL), to assess if it is possible to predict the latter from the former and to evaluate whether height and degree of head extension have any influence on this predictive relationship in Indian patients.

Materials and Methods

The study was designed as an analytical observational study. The protocol was approved by the Institutional Ethics Committee. The study procedure was properly explained to the patient during preoperative check-up and written informed consent was obtained.

One hundred American Society of Anesthesiologists (ASA) grade 1 and 2 adult patients of either sex, presenting for elective surgery under general anesthesia, without any anticipated difficult airway were included. Exclusion criteria of this study were: Patient's refusal; ASA grading 3, 4, and 5; Mallampati classification 3 and 4; restricted neck movement; mandibular joint abnormality; known anatomical defect of face, neck, and upper airway; bleeding diathesis; associated systemic diseases (specially chronic pulmonary disease); and not willing to give written informed consent. They were randomly allocated to two cohorts — a model cohort [Figure 1] and test cohort — using a computer generated random number list. As there is not much data available regarding the length of airway in Indian population and its inter gender variability, the sample size was decided from a pilot study that we had performed on eight sample and we found that 25 subjects would be

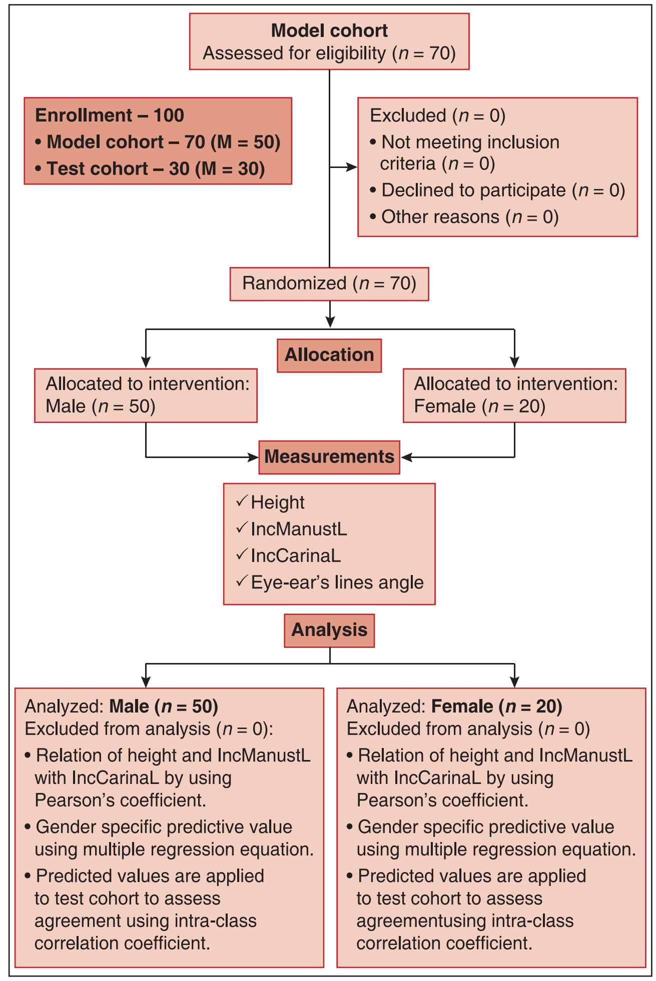

Figure 1: CONSORT-Flow Diagram

required to discover a good correlation (r = 0.7) between the two lengths with 80% power. The idea was to perform this study over model cohort and then apply the result on the test cohort to confirm the accountability of the result. So the correlation between the two lengths was to be explored in the model cohort and regression equations were to be generated using data from this cohort. These equations were then to be used for predicting incisor carina length for subjects in the test cohort and the agreement between actual and predicted lengths to be assessed.

During pre-anesthetic checkup height of the patients was noted down. On the operation table, neck of the patient was extended manually as much as possible and supported by an operator in that position. Then the distance between the upper incisor and the manubrio-sternal joint was measured using a divider and ruler. The degree of maximum head extension was measured indirectly as the eye-ear line's angle (defined as the angle between the lines from the external auditory meatus to supraorbital ridge in both neutral and extended head position).

Baseline vital parameters were recorded. After intravenous (IV) cannulation, anesthesia was induced with IV fentanyl citrate and IV propofol. Endotracheal intubation was facilitated with rocuronium injection. Cuffed endotracheal tubes of 8 and 7 mm internal diameter were used for adult male and female patients, respectively. After confirming the correct position, endotracheal tube was secured at the midpoint of the upper lip with adhesive tape. As we wanted to measure the length of the airway through the ET tube, we tried to keep the ET tube straight and for that purpose we had fixed it at the midpoint of upper lip. Anesthesia was maintained with oxygen in 66% nitrous oxide and 1% isoflurane. Head of the patient was positioned neutrally on the operating table without any head extension or neck flexion. Nitrous oxide was then stopped temporarily; anesthesia being maintained with 2% isoflurane in oxygen for 3 min. With the head in neutral position, the breathing system was detached and a fiberoptic bronchoscope was inserted through the endotracheal tube. The distance between the carina and proximal end of the tube was noted down. The bronchoscope was then taken out and the breathing system reattached to the endotracheal tube to continue anesthesia. This procedure did not take more than 10 s in any patient. During this time and thereafter, the patient was closely monitored for any evidence of desaturation or other airway-related complications like coughing and bucking. The length of the endotracheal tube outside the upper lip of the patient was also measured. After all measurements were completed, surgery was allowed to continue under general anesthesia. The vital parameters of the patient were monitored meticulously throughout the perioperative period. All patients were observed for at least 24 h postoperatively for sore throat or other upper airway symptoms.

Statistical analysis

From sample size calculation, it was estimated that 25 subjects would be required to discover a good correlation ($r = 0.7$) between the two lengths against the null hypothesis of no difference in the two ($r = 0.9$) with 80% power. We aimed to recruit this number separately for male and female subjects, and also the same number for the test cohort. It was therefore planned to recruit 100 subjects containing 70 male and 30 female and allocate them randomly to a model cohort and test cohort. Systat version 11 (Chicago: Systat Software Inc., 2004) software was used for sample size assessment and calculation. So 70 male patients were distributed into model cohort (50 subject) and test cohort (20 subject) by randomization technique; similarly 30 female patients were distributed into model cohort (20 subject) and test cohort (10 subject).

Numerical variables like age, weight, height, ASA grading, and airway lengths have been summarized as mean and standard deviation (SD). The Student's independent samples *t*-test was employed for comparing numerical variables between groups. The paired *t*-test was used for comparing related numerical variables. Fisher's exact test was used for intergroup comparison of counts. Relationship between the two lengths in the model cohort was explored using Bland-Altman plots and scatter plots and by calculation of Pearson's product moment correlation coefficient *r*. Multiple regression analysis of data from the model cohort was used to develop predictive equations for incisor carina length. Predictions were made for subjects in the test cohort and actual and predicted values assessed for agreement using the intraclass correlation coefficient (ICC). The correlation and regression analyses were done separately for male and female study subjects for the model cohort. Key statistics have been presented with their 95% confidence interval (CI) boundaries. $P < 0.05$ has been considered as statistically significant. Statistica version 6.0 (Tulsa, Oklahoma: Stat Soft Inc., 2001) and MedCalc version 11.6 (Mariakerke, Belgium: MedCalc Software, 2011) software were used for statistical analysis.

Results

After random allocation, the 70 subject model cohort included 50 males and 20 females. The corresponding numbers in the 30 subject test cohort were 20 and 10. The demographic profiles of the two cohorts are presented in [Table 1] and they are comparable in this respect.

The mean ± SD IncManustL in the male and female subjects in the model cohort were 25.96 ± 2.5 and 24.49 ± 1.1 cm, respectively. The corresponding IncCarinaL values were 25.66 ± 1.9 and 23.59 ± 1.7 cm, respectively. As shown

Table 1: Baseline variables compared between the two study's cohorts

Baseline variable	Model Male ($n = 50$)	Cohort Female ($n = 20$)	Test Male ($n = 20$)	Cohort Female ($n = 10$)	*P*-value for male	*P*-value for female
Age (year)	45.2 ± 17.04	41.6 ± 11.91	38.5 ± 18.54	30.2 ± 11.91	0.151	0.020
Weight (kg)	56.3 ± 6.85	47.4 ± 7.65	56.6 ± 6.61	50.7 ± 5.08	0.872	0.172
Height (cm)	157.9 ± 4.86	152.0 ± 3.99	155.9 ± 6.31	150.4 ± 3.37	0.159	0.279
ASA grade I/II	34/16	18/2	16/4	8/2	0.390	0.584

Values are depicted as mean ± standard deviation (SD) for the numerical variables, P-values in the last two columns are from comparison between the two cohorts — males and females separately, using independent samples t-test for the numerical variables and Fisher's exact test for American Society Anesthesiology (ASA) grade in [Table 2], this implied that the IncManustL exceeded the IncCarinaL by a mean of <1 cm, with the difference between slightly greater in females than in males. For the test cohort also, a similar relationship was observed, with a mean difference of 0.3 cm in males and 1.3 cm in females.

The relationship between the two lengths have been explored using the Bland-Altman plots depicted in [Figure 2a and b] and the scatter plots depicted in [Figure 3a and b]. The former indicate close agreement, with the majority of the points lying within ± 1.96 SD of the line of mean difference

Table 2: Relationship between upper incisor manubrio-sternal joint length and upper incisor carina length in the two study cohorts

Measurement	Model Male (n = 50)	Cohort Female (n = 20)	Test Male (n = 20)	Cohort Female (n = 10)
Upper incisor manubrio-sternal joint extension length (cm) (A)	25.96±2.47 (16.1-30.8)	24.49±1.11 (23.0-27.1)	26.11±1.71 (22.4-29.0)	24.65±1.34 (22.9-26.5)
Upper incisor carina neutral length (cm) (B)	25.66±1.91 (21.6-29.8)	23.59±1.73 (21.0-27.5)	25.88±1.71 (22.4-29.0)	23.37±1.68 (22.9-26.5)
Difference (cm) between A and B	0.30 (CI 0.21-0.81)	0.90 (CI 0.21-1.59)	0.30 (CI 0.26-0.73)	1.28 (CI 0.39-2.17)

Values for the two lengths are depicted as mean ± standard deviation (SD) with the range in parentheses, CI = 95% confidence interval, The difference between the two lengths is statistically insignificant by paired t-test for males in both cohorts, but is significant for females (P = 0.244 and 0.336 for males in the model and test cohorts, respectively, P = 0.013 and 0.010 for females in the two cohorts, respectively)

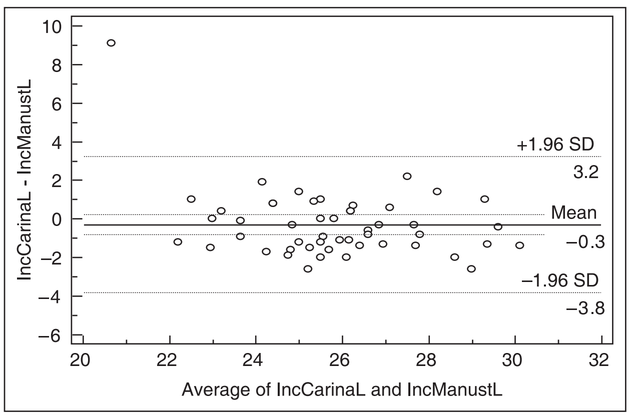

Figure 2: (a) Bland-Altman plot showing positive correlation between upper incisor manubrio-sternal joint length in fully extended head position (IncManustL) and upper incisor carina length in neutral head position (IncCarinaL) for male subjects (n = 50) in the model cohort. All measurements are in centimeters. The bias line is indicated

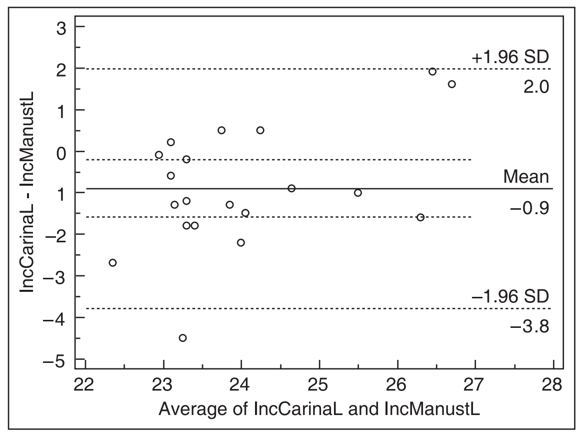

Figure 2: (b) Bland-Altman plot showing positive correlation between upper incisor manubrio-sternal joint length in fully extended head position (IncManustL) and upper incisor carina length in neutral head position (IncCarinaL) for female subjects (n = 20) in the model cohort. All measurements are in centimeters. The bias line is indicated

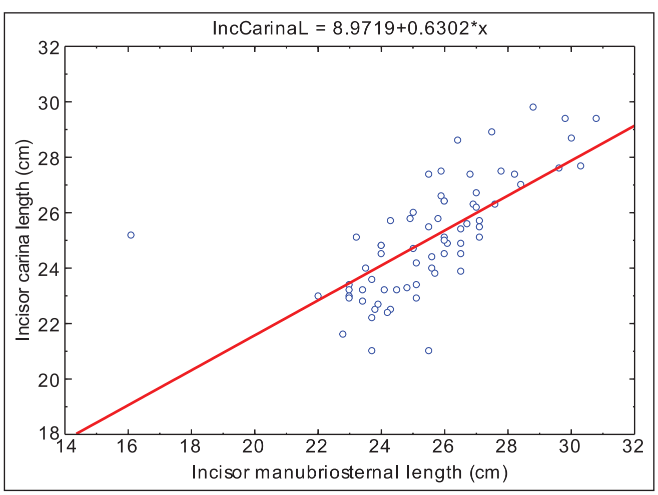

Figure 3: (a) Scatter plot showing positive correlation between upper incisor manubrio-sternal joint length in fully extended head position and upper incisor carina length in neutral head position for male subjects (n = 50) in the model cohort. The regression line and corresponding equations are indicated

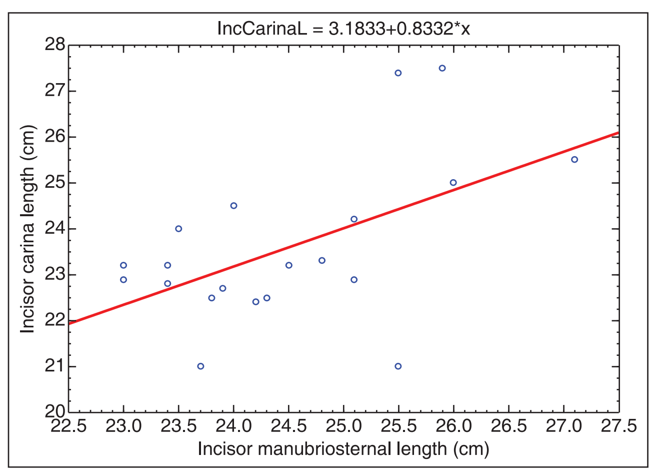

Figure 3: (b) Scatter plot showing positive correlation between upper incisor manubrio-sternal joint length in fully extended head position and upper incisor carina length in neutral head position for female subjects (n = 20) in the model cohort. The regression line and corresponding equations are indicated

(the bias line), for both male and female subjects. The scatter plots indicate the direct linear relationship between the two measurements, with *r* value of 0.69 ($P < 0.001$) for males and 0.54 ($P = 0.015$) for females. The equations of the corresponding regression lines (all measurements in cm) were IncCarinaL = 8.97 + 0.63 × IncManustL (Males) and IncCarinaL = 3.18 + 0.83 × IncManustL (females).

The results of the multiple regression analysis are presented in [Table 3]. Apart from incisor manubrio-sternal joint length, only height was found to be a significant predictor of incisor carina length. Age, weight, and the angle of neck extension did not matter. The coefficient of determination (r^2) was 0.63 for the male and 0.71 for the female model cohort. The multiple regression equations obtained were (all measurements in cm) IncCarinaL = 0.3564 × IncManustL + 0.1719 × height-10.7335 (Males) and IncCarinaL = 0.6738 × IncManustL+ 0.2628 × height-32.8541 (females).

These gender-specific multiple regression equations were used for predicting the incisor carina length for the 30 subjects in the test cohort. The actual and the predicted values are depicted in [Table 4]. The ICC for absolute agreement between the two sets of values was 0.723 (95% CI 0.495-0.858), irrespective of gender. This indicates a strong agreement. The expected margin of error, irrespective of gender, would be 0.16-0.90 cm on the basis of the 95% CI of the difference between actual and predicted values.

Therefore, we propose that these equations, which require simple measurement of stature and upper incisor manubrio-sternal joint length in fully extended head position, can be used for predicting incisor carina length before attempting endotracheal intubation in Indian subjects.

Discussion

Malposition of the endotracheal tube is a known and preventable complication. To prevent endobronchial intubation or accidental extubation, it has been advocated that the tip of the tube should be kept at the middle part of the trachea. Conrardy and coworkers[16] reported that neck flexion from a neutral head position can advance the tube towards the carina up to 3.1 cm. Similarly, it can move up to 5.2 cm away from the carina during neck extension. During rotation of neck the endotracheal tube tip moves significantly away from the carina. Therefore, these authors have recommended that the ideal position of endotracheal tube tip within the trachea should be 5 ± 2 cm from carina.[17]

Based on these observations, clinicians attempt to keep the endotracheal tube tip in mid-trachea, by intubating the patient under direct vision and keeping the upper border of the cuff beyond the vocal cords.[6] Position of the endotracheal tube can be checked; especially in patients who need prolong intubation; by light wand,[18]fiberoptic bronchoscope, and chest X-ray. However, these are difficult to implement in routine anesthesia practice in resource constrained settings. Therefore, attempts have been made to assess the distance between the upper incisor and the carina, utilizing various anatomical landmarks.

In 1992, Eagle[13] failed to find a foolproof relationship between height of a person and length of the trachea. However, he observed good correlation of patient's height with incisor-vocal cords length and external nare-vocal cords length. Techanivate*et al.*,[7] found moderate correlation between height of a person and canine to carinal length (Pearson's $r = 0.707$) in Thai adults. Although the height and incisor carina length of male and female subjects in our study were less as compared to Western populations, we also observed good positive correlation between height and airway length ($r = 0.679$; $P < 0.001$ for males and $r = 0.679$; $P = 0.003$ for females). These observations suggest that it is possible to discover good correlations between external anatomical measurements and airway length.

According to Morgan,[19] length of oral endotracheal tube (cm) = height of the patient (cm)/10 + 5. Techanivate and coworkers[7] suggested 'Chula formula' for determining

Table 3: Output from multiple regression analysis for incisor carina length in the model cohort

Independent variable	Males (n = 50)				Females (n = 20)			
	Regression coefficient	Standard error	*t*	*P*-value	Regression coefficient	Standard error	*t*	*P*-value
IncManustL	0.3391	0.08806	3.851	0.0004	0.5333	0.2419	2.204	0.0447
Age	−0.003581	0.01060	−0.338	0.7371	0.03957	0.02441	1.621	0.1272
Weight	−0.01810	0.02747	−0.659	0.5134	0.3151	0.08754	3.599	0.0029
Height	0.1883	0.04666	4.035	0.0002	0.008092	0.04185	0.193	0.8495
Angle of neck extension	0.02738	0.02785	0.983	0.3309	−0.06265	0.05728	−1.094	0.2925
r^2	0.628				0.712			

IncManustL = Upper incisor manubriosternal joint length in extended head position, r^2 = coefficient of determination, It may be noted that the significant predictors are IncManustL and height, The gender-specific regression equations are presented in the text

Table 4: Actual and predicted upper incisor carina lengths in the test cohort

Sex	Actual length (cm)	Predicted length (cm)	Difference (cm)
Male	26.80	24.32	2.48
Male	25.20	23.62	1.58
Male	22.50	22.61	−0.11
Male	24.00	23.33	0.67
Male	24.40	25.13	−0.73
Male	26.30	26.84	−0.54
Male	25.30	26.11	−0.81
Male	26.80	26.49	0.31
Male	23.80	24.76	−0.96
Male	23.90	24.55	−0.65
Male	24.90	24.66	0.24
Male	27.00	24.59	2.41
Male	28.70	29.31	−0.61
Male	28.10	27.36	0.74
Male	27.10	26.27	0.83
Male	27.10	25.48	1.62
Male	28.10	24.53	3.57
Male	26.50	25.54	0.96
Male	26.90	27.21	−0.31
Male	24.10	24.72	−0.62
Female	22.20	24.33	−2.13
Female	23.70	23.26	0.44
Female	24.50	23.63	0.87
Female	24.30	24.48	−0.18
Female	22.00	21.47	0.53
Female	20.70	23.59	−2.89
Female	23.80	22.39	1.41
Female	21.50	22.27	−0.77
Female	25.50	24.67	0.83
Female	25.50	22.58	2.92
Summary	25.04±2.06	24.67±1.73	0.37±1.41 (CI 0.16-0.90)

The actual upper incisor carina length in neutral head position is from measurement by fiberoptic bronchoscopy as explained in the text, The predicted length has been obtained by applying the gender-specific multiple regression equations derived from the model cohort, The summary values for the two lengths and their difference are depicted as mean ± standard deviation (SD), CI = 95% confidence interval, The difference between the two lengths is statistically insignificant by paired t-test (P = 0.163), The intraclass correlation coefficient for absolute agreement irrespective of gender was 0.723 (CI 0.495-0.858)

required length of the endotracheal tube. According to that formula, length of oral endotracheal tube (cm) = height of the patient (cm)/10 + 4 and length of nasal endotracheal tube (cm) = height of the patient (cm)/10 + 9. However, height may not be an acceptable predictor of airway in all populations.[13] Chong *et al.*,[20] found that tracheal length in Chinese adults had only a moderate correlation ($r = 0.51$) with height of the individual. They also observed that the patient with ≤167.5 cm height had higher probability for short trachea. An anatomical study with cadavers from Bangladesh[21] found lower value for tracheal length compared to western population, with the length increasing with increasing age. Our findings are expected to be similar since the Bangladeshi study population is ethnically close to our study cohort. However, we did not find age to be a significant predictor of airway length.

Other anatomical landmarks have also been used for prediction of airway length with variable success. Cherng and co-workers[14] used both height and sternum length for prediction of airway dimension. They observed good correlation of sternal length with tracheal length, but not with incisor carinal length. Han *et al.*,[22] used two anatomical landmarks along with height of a person, that is, nare to tragus distance and nare to angle of mandible distance, for prediction of nare to vocal cords distance. Evron and coworkers[23] used topographic methods for detection of airway length. They added the distance measured from right mouth corner to right mandibular angle to the distance measured from right mandibular angle to the center of a line drawn transversely through the middle of the sternal manubrium. They found that this simulated airway length is very similar to true airway length. In a recent study, Patel *et al.*,[24] positioned the endotracheal tube externally along the neck parallel to the path of anticipated airway. They were also successful to keep safe distance between tube tip and carina.

Lee and coworkers[15] predicted that straight length from the upper incisor to the manubriosternal joint in fully extended head position would be similar to airway length (incisor carina length) because during rigid bronchoscopy in extended neck position, airway is aligned in straight line. Therefore, they compared upper incisor manubriosternal joint length with upper incisor carina length and found a strong positive correlation ($r^2 = 0.88$ for adults and 0.98 for children).

We also found good positive correlation between upper incisor manubrio-sternal joint length and upper incisor carina length in male and female adult subjects, though not as strong as in the study by Lee *et al.*[15] The correlation was stronger in males. Similar to that study, we did not find any relationship between age, weight, or degree of neck extension and airway length, that is, incisor carina length. However, we did observe an association between height and incisor carina length. Therefore, we decided to use the equations from multiple regression analysis (incorporating incisor manubrio-sternal length and height) for predicting airway length in the test cohort, rather than the equations from simple linear regression.

The multiple regression equations successfully predicted the airway-carina length for subjects in the test cohort. The ICC value indicates strong agreement and the margin of error is modest.

Still, our study has some limitations. The number of female subjects in the model cohort fell short of the calculated sample size of 25. This could have been avoided if we had followed a stratified randomization procedure rather than simple randomization. Inclusion of greater number of subjects in the female model cohort may have improved the predictive accuracy of the multiple regression equation for females. The other obvious limitation is that the results are not generalizable to other populations of subjects, such as children or those with anticipated difficult airway, without further studies. Finally the strategy would fail if full neck extension is not possible in a subject for measurement of the upper incisor manubriosternal length.

Notwithstanding these limitations, in conclusion, we can say that in adult Indian subjects it is possible to predict airway length (upper incisor carina length in neutral head position) by making two simple anatomical measurements beforehand, namely stature and upper incisor manubrio-sternal joint length in fully extended head position. Then one of the following equations needs to be applied with all measurements being in centimeters:

Male: $\text{IncCarinaL} = 0.356 \times \text{IncManustL} + 0.172 \times \text{height} - 10.734$

Female: $\text{IncCarinaL} = 0.674 \times \text{IncManustL} + 0.263 \times \text{height} - 32.854$

Knowing the length predicted by these equations, the endotracheal tube tip can be positioned in the middle part of trachea keeping a safe distance from vocal cords and carina. The actual degree of neck extension of the subject will not influence correct positioning if this distance is used.

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References

1. Blanc VF, Tremblay NA. The complications of tracheal intubation: A new classification with review of the literature. AnesthAnalg 1974;53:202-13.
2. Holland R, Webb RK, Runciman WB. The Australian Incident Monitoring Study. Oesophageal intubation: An analysis of 2000 incident reports. Anaesth Intensive Care 1993;21:608-10.
3. McCoy EP, Russell WJ, Webb RK. Accidental bronchial intubation. An analysis of AIMS incident reports from 1988 to 1994 inclusive. Anaesthesia 1997;52:24-31.
4. Caplan RA, Posner KL, Ward RJ, Cheney FW. Adverse respiratory events in anaesthesia: A closed claims analysis. Anesthesiology 1990;72:828-33.
5. Sugiyama K, Yokoyama K. Displacement of the endotracheal tube caused by change of head position in paediatricanaesthesia: Evaluation by fibreoptic bronchoscopy. AnesthAnalg 1996;82: 251-3.
6. Mehta S. Intubation guide marks for correct tube placement. A clinical study. Anaesthesia 1991;46:306-8.
7. Techanivate A, Rodanant O, Charoenraj P, Kumwilaisak K. Depth of endotracheal tubes in Thai adult patients. J Med Assoc Thai 2005;88:775-81.
8. Knapp S, Kofler J, Stoiser B, Thalhammer F, Burgmann H, Posch M, *et al.* The assessment of four different methods to verify tracheal tube placement in critical care setting. AnesthAnalg 1999;88:766-70.
9. Sosis MB, Harbut RE. A caution on the use of routine depth of insertion of endotracheal tubes. Anesthesiology 1991;74:961-2.
10. Verghese ST, Hannallah RS, Slack MC, Cross RR, Patel KM. Auscultation of bilateral breath sounds does not rule out endobronchial intubation in children. AnesthAnalg 2004;99:56-8.
11. Hughes JM, Hoppin FG Jr, Wilson AG. Use of stereoscopic x-ray pairs for measurements of airway length and diameter *in situ*. Br J Radiol 1972;45:477-85.
12. Dietrich KA, Strauss RH, Cabalka AK, Zimmerman JJ, Scanlan KA. Use of flexible fiberoptic endoscopy for determination of endotracheal tube position in the pediatric patients. Crit Care Med 1988;16:884-7.
13. Eagle CC. The relationship between a person's height and appropriate endotracheal tube length. Anaesth Intensive Care 1992;20:156-60.
14. Cherng CH, Wong CS, Hsu CH, Ho ST. Airway length in adults: Estimation of the optimal endotracheal tube length for orotracheal intubation. J ClinAnesth 2002;14:271-4.
15. Lee BJ, Yi JW, Chung JY, Kim DO, Kang JM. Bedside prediction of airway length in adults and children. Anesthesiology 2009;111:556-60.
16. Conrardy PA, Goodman LR, Lainge F, Singer MM. Alteration of endotracheal tube position. Flexion and extension of the neck. Crit Care Med 1976;4:7-12.
17. Goodman LR, Conrardy PA, Laing F, Singer MM. Radiographic evaluation of endotracheal tube position. AJR Am J Roentgenol 1976;127:433-4.
18. Stewart RD, LaRosee A, Stoy WA, Heller MB. Use of lighted stylet to confirm correct endotracheal tube placement. Chest 1987;92:900-3.
19. Morgan GA. An orotracheal tube with laryngeal hooks. Anaesthesia 1989;44:82.
20. Chong DY, Greenland KB, Tan ST, Irwin MG, Hung CT. The clinical implication of the vocal cords-carina distance in anaesthetized Chinese adults during orotracheal intubation. Br J Anaesth 2006;97:489-95.
21. Begum T, Naushaba H, Alam J, Paul UK, Alim AJ, Akter J, *et al.* Cadaveric length of trachea in Bangladeshi adult male. Bangladesh J Anat 2009;7:42-4.
22. Han DW, Shim YH, Shin CS, Lee YW, Lee JS, Ahn SW. Estimation of the length of the nares-vocal cord. AnesthAnalg 2005;100:1533-5.
23. Evron S, Weisenberg M, Harow E, Khazin V, Szmuk P, Gavish D, *et al.* Proper insertion depth of endotracheal tubes in adults by topographic landmarks measurements. J ClinAnesth 2007;19:15-9.
24. Patel N, Mahajan RP, Ellis FR. Estimation of the correct length of tracheal tubes in adults. Anaesthesia 1993;48:74-5.

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